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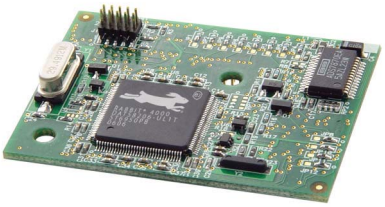

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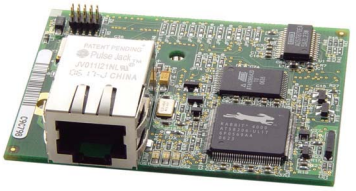

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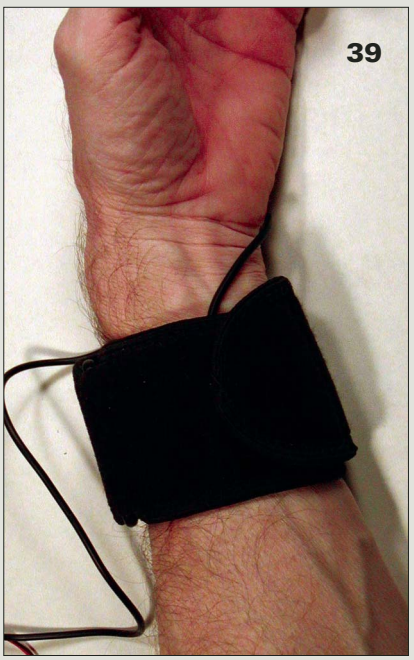

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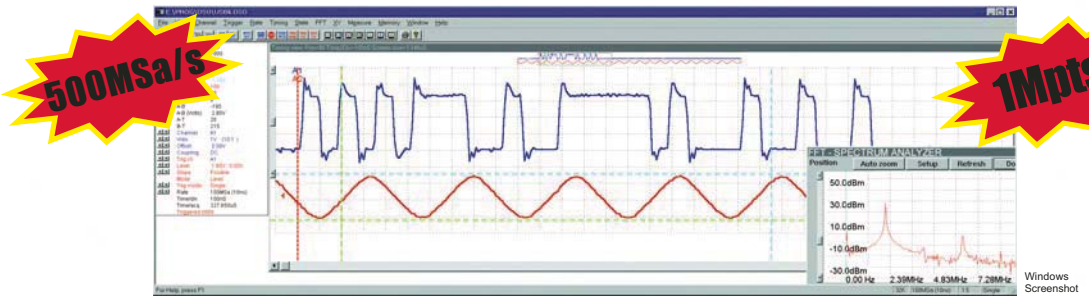

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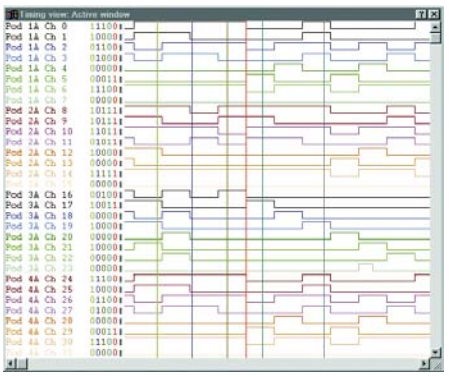

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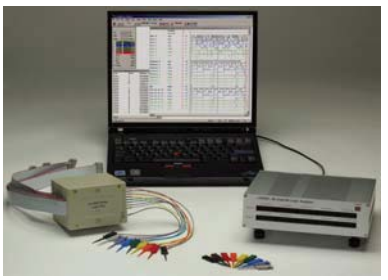

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READER FEEDBACK

HOT FOR ANSWERS ABOUT FURNACE

Kenton Chun's recent article (Dec '06) was particularly timely and helpful considering our recent, long, and cold power outage. During this period, our house temperature fell to 38 very cold degrees.

I would like to undertake the project proposed by Kenton's article. However, I have one major concern. I own a Carrier 58MVP gas-fired furnace. This furnace is very modern and very efficient. To achieve this, the furnace does contain some circuit cards and other components which might (I am not sure) be considered sensitive to something less than "pure" sine wave inverter output.

Above-all, I do not want to toast my very expensive furnace in this process. Nor do I want to purchase an inverter that will ultimately not meet my needs for emergency heat in the future.

So, I wonder (obviously, I know nothing about all this — sorry for any newbie questions):

(a) How can I tell if my furnace requires "pure" sine wave power or not without taking a risk of doing any damage in empirical tests? I know that my furnace can be run via generator — I have been told this by both a local dealer and read individual accounts of this being done on the web. Do generators produce "pure" sine wave power?

(b) I read various inverter vendors speak of their products having "clean" power. Is "clean" power the same as "pure" sine wave power? If not, what does this mean?

(c) If a "modified" sine wave output will work, are some forms of "modified" sine wave output better (more "clean") than others? How can I tell? If the vendors publish specs, what should I look for?

(d) Kenton specifically mentions a trace inverter with 2400 watts. Is "trace" a brand name or is it some type or specialty within the inverter field? I have seen something called a "Trace" made by Xantrex on the web. Is this the unit Mr. Chun used?

(e) I plan — in case of another power emergency — to run the furnace from my car's battery. I don't expect to do this without the car running at idle. This will turn my car into the most expensive and inefficient generator known. But will this work? It sounds like it did when the trace inverter was run from Mr. Chun's van.

(f) Inside my furnace, a notice by the junction box specifically says to NOT wire neutral to ground. I have read on the web a case where some folks had difficulty powering the furnaces via generator due to neutral being wired to ground in their generators (a Honda, I believe). Is this going to be a problem/issue using an inverter? If so, how can I tell if a particular brand/model is going to be a source of this problem.

Sorry for carrying on too long. But I am so ignorant of these matters that I want to be sure I do the right thing.

David White
Seattle, WA

Author Response:

Thank you for your interest and feedback! The concept I described in the article will work well with gas-fired furnaces provided the inverter is correctly sized to the furnace's power requirements. Most recently manufactured "modified sine wave" inverters will have a sufficiently "clean" output to run any electrical appliance, including sensitive electronic devices (like computers) safely. If you have any doubts or concerns about whether a specific inverter will safely power your home furnace, consult the manufacturer(s). Xantrex purchased Trace Engineering a number of years ago and is now the manufacturer of all Trace power products.

Continued on Page 47

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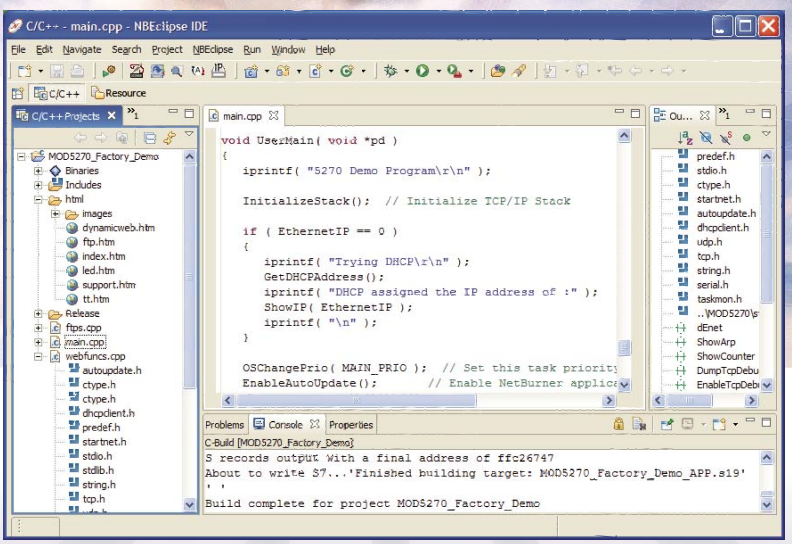

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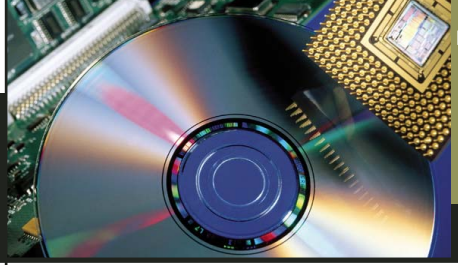


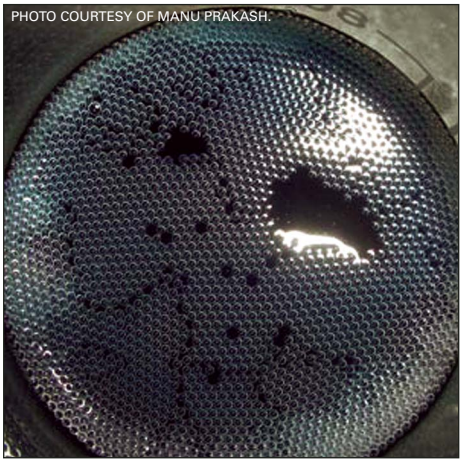
TECH KNOWLEDGEY 2007

EVENTS, ADVANCES, AND NEWS

■ BY JEFF ECKERT

ADVANCED TECHNOLOGY

BUBBLES ARE BACK?



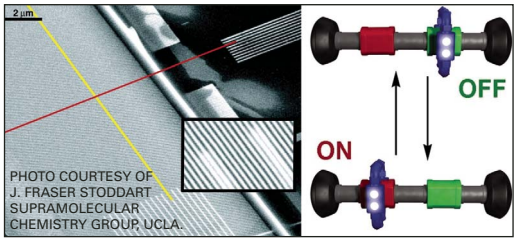
■ MIT researchers have developed a computer chip that runs on microbubbles like these.

It looks a little like a damaged compound eye from a mechanical insect, but what you're really looking at is a new device that could derive — among other things — computing capabilities from microfluid bubbles. A team of scientists from MIT's Center for Bits and Atoms (**http://cba.mit.edu/**) recently reported the development of "bubble logic," which "merges chemistry with computation, allowing a digital bit to carry a chemical payload." This should not be mistaken for the bubble memories of a few decades ago, which showed promise but ultimately were too slow and expensive for widespread commercialization.

Although bubble logic functions in a manner that is analogous to electronics, what you really have is a tiny chip in which nanoliters of fluid flow from one part to the other and undergo controlled chemical reactions. Instead of using electrical states to indicate a 1 or a 0, it bases its logic on the presence or absence of a bubble.

The demonstrated approach employs nitrogen bubbles in water, but you can use pretty much any two substances that don't mix (e.g., oil and water, wine and whiskey). The team has demonstrated, at least in theory, all elements needed for any new logic family, including gates, memories, amplifiers, and oscillators. One main drawback at this point, however, is speed — they run about 0.1 percent of the speed of a typical microprocessor, so a computer driven by them would have slightly more power than a Commodore VIC-20. But the devices may also prove useful in programmable print heads and various medical applications.

BUT MAYBE MOLECULES ARE MORE MIRACULOUS



■ These switches store information in an ultra-dense 160 kilobit memory made up of a 400 x 400 grid of nanowires (left).

Approaching high logic density from a different direction is a project from UCLA (**www.ucla.edu**), where researchers have created a dense memory device, said to be about the size of a white blood cell, that could be an important step toward the creation of molecular computers to replace today's silicon-based technology.

The switches (right side of illustration) are made up of a molecular ring that encircles the dumbbell-shaped molecule. When the switch is triggered, the ring slides between two locations to control conductivity. The present device contains 160 kbits that are arranged on a grid (left side of illustration) of nanowires (400 silicon crossed by 400 titanium, each 16 nm wide), with a layer of the switches sandwiched between the wires.

Commercial use of the concept is still a few years off, but one of the collaborators noted, "Our goal was not to demonstrate a robust technology; the memory circuit we have reported on is hardly that. Instead, our goal was to demonstrate that large-scale, working electronic circuits could be constructed at a density that is well beyond (10-15 years) where many of the most optimistic projections say is possible."

COMPUTERS AND NETWORKING

ELECTRONIC PRESCRIPTIONS ON THE WAY

The notoriously bad handwriting of physicians has been a joke for as long as anyone can remember, but when it comes to writing prescriptions, some of the humor disappears. According to the National ePrescribing Safety Initiative (NEPSI, **www.nationaleRx.com**), medication errors injure at least 1.5 million Americans and kill 7,000 every year. Although many of these are unrelated to penmanship and are caused by common adverse reactions and such, it does appear that switching US doctors over to electronic prescription filing could improve the situation. Unfortunately, fewer than 1 in 5 MDs have adopted it, so NEPSI, a coalition of health care and technology companies too numerous to mention, is now providing such capabilities free of charge.

The backbone of the NEPSI program is eRx NOW™ — web-based software from Allscripts (**www.allscripts.com**) powered by the same engine used today by more than 20,000 physicians already. Designed for physicians in solo practice or small

groups, eRx NOW is available free to any health care provider with legal authority to prescribe medications, and it requires no download, no new hardware, and minimal training.

The product includes the ability to generate secure electronic prescriptions that can be sent computer-to-computer or via electronic fax to 55,000 retail pharmacies via Sure Scripts Messenger Service (**www.surescripts.com**). Prescriptions are checked for potentially harmful interactions with a patient's other medications, and the product includes the ability for physicians to search and find targeted health-related information using a custom search engine from Google.

And in case you're worried about your medical records, note that eRx NOW includes multiple redundant layers of firewall; deep-packet inspection; SSL encryption; database encryption; intrusion detection; and virus, spyware, and malware protection for the program's remote servers. So, physician, heal thyself. After all, it's free.

STOP EMBARRASSING LEAKAGE

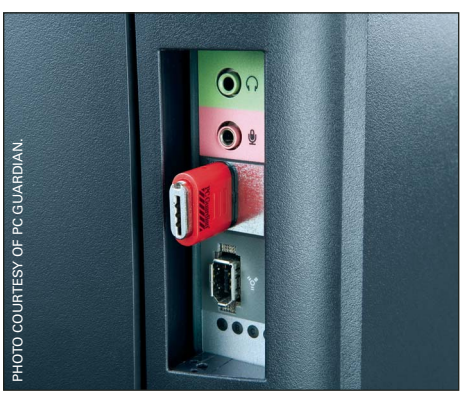


PHOTO COURTESY OF PC GUARDIAN.

■ This USB lock is designed to provide data protection for various digital devices.

The USB Port Security System from PC Guardian (**www.pcguardian.com**) may not be the highest-tech product you'll run into, but it looks like a good bet if you are worried about data leakage, data theft, computer viruses, and malware that passes through USB ports of your computer. Capable of protecting single or multiple USB ports in various configurations, it was developed in response to the ever-increasing threat of unauthorized data transfer through USB ports to Flash drives, memory sticks, MP3 players, and other mobile storage devices.

The USB Port Security System is compatible with most USB ports on the market today. The pushbutton lock is available in different keying options, and multiple configurations are available to secure from one to seven USB ports. The locks are priced at $12.95 to $71.95, depending on configuration and components.

FREE VIDEO SOFTWARE

In a continuing effort to inform readers about useful freebies, we present Prism v. 1.00, from the folks down under at NCH Software. The Canberra-based outfit specializes in business and video software and has just released a video file converter for Windows 98 onward, including Vista.

It's basically just a file converter that converts avi, mpg, vob, asf, wmv, mp4, ogm, and all video formats that have a DirectShow based codec to AVI and Windows Media Video formats, and it's available for download at **www.nchsoftware.com/prism/index.html**. (DirectShow, formerly called ActiveMovie, is Microsoft's graphic driver for various formats.)

CIRCUITS AND DEVICES

DEVICE COUNTS PASSENGERS

■ The PCN-1001 Passenger Counter is based on noncontact stereoscopic vision technology. PHOTO COURTESY OF EUROTECH S.p.A.

It's not as if one in a million of us would ever need one, but Eurotech's PCN-1001 Passenger Counter falls into the category of "interesting stuff you probably never knew existed." The Italian company (**www.eurotech.it**) builds computer systems for public transportation vehicles, and the PCN-1001 is intended to work with a vehicle server that can preprocess, store, and upload information from it. It employs a vision detection technology that combines stereoscopic cameras with high-luminosity infrared LEDs, and an advanced interpretation algorithm is said to provide detection accuracy better than 97 percent under all lighting conditions, in anything ranging from tropical to arctic conditions.

The central control units can also provide asset management, security and surveillance, diagnostics and fleet monitoring, wireless communication, and information services. Isolated digital inputs and outputs can be used to control devices on the vehicle, detect door position, or to trigger external systems. And apparently, vandalism is common in Italy, as well as in the US, because the counter is enclosed in a sealed, solid magnesium enclosure with locking automotive-grade connectors.

LOW-COST SERIAL ANALYZER

PHOTO COURTESY OF MICROCHIP TECHNOLOGY.

■ This new tool enables design engineers to interface with circuits that are embedded deep within serial systems using any Windows®-based PC.

The latest from Microchip Technology, Inc. (**www.microchip.com**) — a provider of microcontroller and analog semiconductors — is the PICkit™ Serial Analyzer, an addition to the PICkit development tool series. It is designed for engineers who develop firmware to communicate via serial communication protocols to components typically found in embedded systems.

The instrument comes with a 28-pin demo board populated with a PIC16F886 mid-range eight-bit microcontroller. The kit's hardware and graphical user interface (GUI) software allow communication between the PC

INDUSTRY AND THE PROFESSION

POSTHUMOUS AWARD FOR HYBRID ENGINEER

In February, engineer Victor Wouk, widely known as the "father of modern hybrid programs," was posthumously given the Elmer A. Sperry Award by the Society of Automotive Engineers (SAE, **www.sae.org**) for his "visionary approach to developing gasoline engine-electric motor hybrid-drive systems for automobiles and his distinguished engineering achievements in the related technologies of small, lightweight, and highly efficient electric power supplies and batteries."

In the 1970s, Wouk and partner Charles Rosen founded Petro-Electric Motors and modified a 1972 Buick Skylark to operate from a Mazda rotary engine and an electric motor, thus creating the first full-sized hybrid automobile. Although the car performed well, the Environmental Protection Agency ultimately (and probably falsely) claimed that it did not meet Clean Air Act emission standards, which led to the demise of Petro-Electric.

IBM TO DUMP PRINTING DIVISION

It was recently announced that IBM (**www.ibm.com**) is forming a joint venture with Ricoh Co. (**www.ricoh.com**) under which the latter will acquire 51 percent of the former's Printing Systems Division. Over the next three years, Ricoh will acquire the other 49 percent of the company, which is to be named InfoPrint Solutions Co.

Ricoh will pay $725 million (which includes a tidy management fee of $35 million) for its initial controlling interest, with the price for the remainder being based on future profitability of the company. In 2006, the division generated approximately $1 billion in revenues. In 1991, IBM spun off its low-end printer division, which became Lexmark.

and several industry-standard serial protocols on the microcontroller being tested, including I^2C, SPI, and USART.

Included are user's guides for both the PICkit serial analyzer and the 28-pin demo board, complete source code, selected application notes, and Microchip's free MPLAB® IDE integrated development environment. The tool is available now for the paltry sum of $49.95.

MOBILE PHONE HAS MORE

The day has not arrived when your cell phone will replace all of your other gadgets, but it's getting closer. The latest step in that direction in the Samsung Ultra lineup is the Ultra Smart F700, introduced at the 3GSM World Congress. The instrument offers both a full touch screen and a QWERTY key pad, plus the company's VibeTonz technology that makes the buttons vibrate. A drag-and-drop method of touch screen operation offers easier menu navigation along with music play list control for an expanded multimedia experience. Volume, play lists, screen brightness, and other menu options can be controlled via the touch screen.

■ Samsung's Ultra Smart F700 offers both a touch screen and QWERTY key pad.

The Ultra Smart is built to handle data speeds of 7.2 Mbps under the High Speed Downlink Packet Access (HSDPA) network. Once the network is completely deployed, F700 users will be able to download an MP3 tune in less than five seconds. You also get a full HTML browser for email and data services, a 5 Mpixel camera with autofocus, and Bluetooth, all in a package measuring only 104 x 50 x 16.4 mm (approx. 4 x 2 x 0.65 in). **NV**

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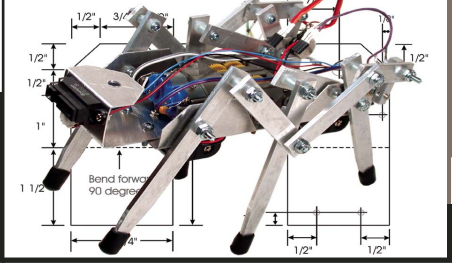


■ BY PHIL DAVIS

PARAMETERS ON THE FLY: Part 2

LAST MONTH, I CONCEPTUALLY DESIGNED A hand-held console which would allow one to remotely change critical parameters in their autonomous robot. Since last month, I decided that I wanted to go into more detail on the software and some of the hardware components — specifically the Blue Tooth card — so rather than finish the article up this month, I am making it a three-parter.

The idea behind this device is to allow the changing of those variables which are typically used to tune or control the robot. For example, if you have a robot that is designed to stop four inches from a wall, then you will probably have a distance sensor and a variable containing four, and the bot will stop when the distance sensor matches the variable.

However, when building your robot you find that due to inaccuracies in the distance sensor, your robot actually stops six inches from the wall. Typically, the only way to fix this is to edit your code, recompile the program, and download in into the robot. You might find you have to do this many times to get it just right. With the hand-held console we are building, however, you will be able to do this on the fly, without having to change the code.

The main component of the hand-held console is going to be the RF module as this allows communication between the bot and the console to take place. This being the case, I chose Blue Tooth since it has a range sufficient for our purposes and is fairly easy to connect.

THE EB500 EMBEDDED BLUE MODULES

These terrific little Blue Tooth cards are manufactured by A7 Engineering and can be obtained from Parallax (see Photo 1). These cards are designed to be used specifically for use with Parallax's AppMod header and, in that configuration, are very easy to use. However, as I am going to connect these to my Mega32 board, I need to know about the pinouts in a little more detail.

As you can see from Photo 1 of the EB500, there are two rows of 10 pins for a total of 20. These pins have various functions, but for now, the ones I am interested in are power and TTL serial communications:

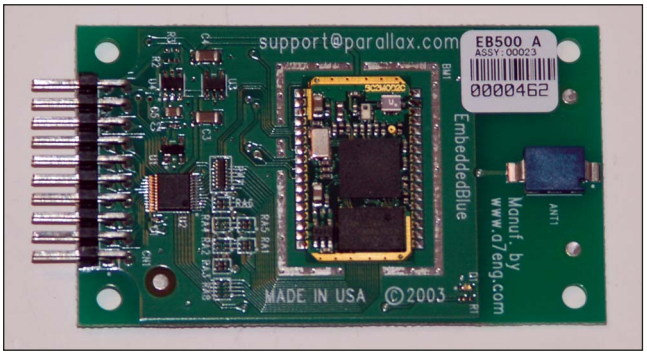
Power
- GND — pin 1
- VCC — pin 20

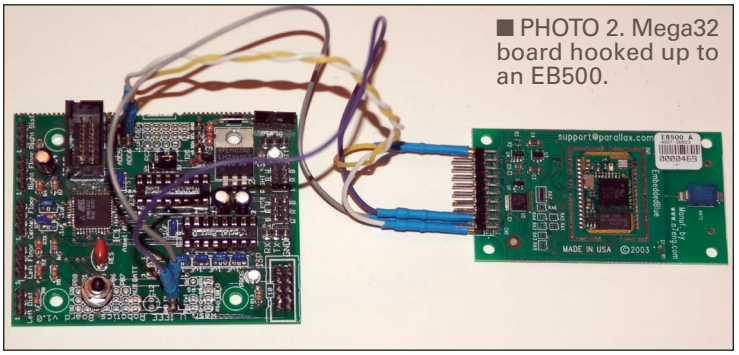
Comms
- RX — pin 3
- TX — pin 4

If you look at Photo 2, you can see how I have connected this up to my Mega32 board. I basically located a header on my CPU board which had GND and VCC and cabled that up to pins 1 and 20 on the EB500. Since the serial interface on the EB500 is at TTL levels, I removed the RS-232 driver chip on my board and connected pins 3 and 4 from the EB500 directly to pins 9 and 10 of the Mega32. My board has a header that exposes these two pins. Photo 3 shows the EB500 connected to my STK500.

The EB500 has additional pin output signals such as connection status and mode control, which I may use later, but for now, I'm just using power and comms. Note also, the long single wires can be replaced later

■ PHOTO 1. Parallax EB500 embedded Blue Tooth card.





■ PHOTO 2. Mega32 board hooked up to an EB500.

with a header and some neater wiring.

Since I will be using an identical Mega32 board at both the console side and the robot side, the connections and wiring will be identical.

EB500 OPERATION

The EB500 has two basic modes of operation: Command and Data. In Command mode, the user can issue various commands to cause certain actions. In Data mode, the device acts like a "cordless" RS-232 connection and all input is passed through.

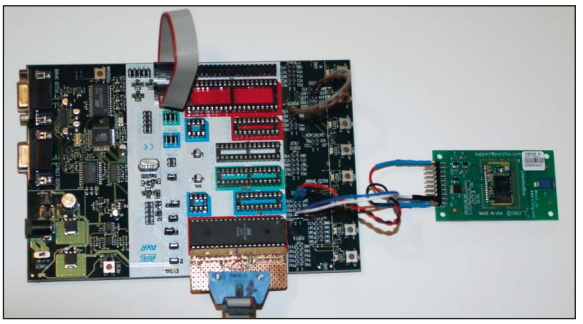
In Command mode, there are several commands available, though I will only be using a small subset of these, namely "connect" and "get address." There are a number of other interesting commands and capabilities, most notably the ability to have encryption and trusted devices.

DATA TRANSMISSION

The whole point of the hand-held console is to have the robot send its set of variables to the console and then to let the user change those parameters and send them back to the robot. The data being transmitted may consist of some ASCII characters as part of the protocol between the two devices, for example, "respond," "var," "ready," etc. However, the data being transmitted also consists of variables and the variables will contain non-ASCII data, such as a binary 1 or a binary 2 etc., so special accommodations need to be made for this type of non-ASCII data. We will also have to delineate a message. That is, we will need to build each message into a packet, with a header and a trailer; in this case, very simple ones.

To this end, we need a simple packet protocol and a way to ensure the transmission of binary data. It just so happens that my robotics buddy, Ken Tait, uses such a protocol and with his permission, I am briefly going to describe a version of it.

Regardless of what the contents of the messages sent back and forth are, we are going to wrap them in a header and trailer. This way, we will know where the beginning of the message is and where the end of the message is.



■ PHOTO 3. EB500 connected to a STK500 with a Mega32.

For this we will use the ASCII characters:

Header: STX (hex 02)
Trailer: ETX (hex 03)

When a message comes into either the bot or the Console, the first thing we will do is look for an STX character and wait for an ETX character. Then we will know the stuff in the middle is the message. However, as mentioned before, we need to take into consideration binary data. Why — you might ask — since we encapsulate our message with STX/ETX. Well, we have to consider what would happen if part of the data being transmitted is a binary 2 or a binary 3, since these could be mistaken for either an STX or an ETX.

To solve this problem, we will incorporate into our packet construction a search for any of these characters in the data of the message. If we find one, we will insert a character before it marking its position and then follow it with the actual character. For this mark character, we will use:

Mark: SOH (hex 01)

As an illustration, let's say we have a message of two bytes each containing the following:

Byte 1: hex 03
Byte 2: hex 41

Following the rules above, we would then construct a packet as follows, using a '|' to separate each byte for clarity:

STX|SOH|0x03|0x41|ETX

As you can see, our packet grew from a length of two to a length of five, but we are able to determine the beginning and the end, as well as not confuse any binary data with the STX, ETX, or the SOH since this is also a reserved character.

When we deconstruct this packet, we essentially reverse the process. The STX tells us this is the start of the packet and the message, the next SOH tells us that the following character could be an SOH, STX, or ETX, and should be treated literally. When we find an SOH, we throw it away and take the next character as-is. Finally, moving through the rest of the data we find the ETX that is not preceded by an SOH and we then know that is the end of the message and packet.

So, if we use this simple technique to construct and deconstruct the packets, we can be assured of sending both ASCII and binary data back and forth. Note also, there is no attempt at error detection or correction and it is assumed that all data will be received accurately, which I think is fine for this level of robotics.

PROTOCOL

Packetizing and sending data back and forth is not quite enough. We now need to develop a simple protocol we can layer on top of it and use to identify requests and responses, as well as a 'standard' method for packing the information. As an example, these are some of the commands we will need to pass the variables back and forth:

• *respond* — Sent by the console to the bot when the console first powers up and after the EB500s become connected.

• *ready* — Sent by the bot to the console to acknowledge it is ready and running. This is in response to receipt of "respond." May be sent by the console to the bot to acknowledge it is ready and running.

• *send* — Sent by the console to the bot once communication has been

established or at any time after if the variables are required to be reloaded. This command requests that the bot transmit all the variables in its param array to the console.

• *var N* — Sent by the bot to the console in response to the 'send' command or sent by the console to the bot when a variable has been changed. Here, 'N' represents the zero based variable number, e.g., 1 for the second variable in the param array.

Of these commands, "var" is the more difficult as it will contain the properties relating to a specific variable. Last month, I described the properties of a variable in the param array. This month, I want to simplify it slightly to illustrate the "var N" command, so let us assume the properties are:

```
struct {
        char    name[9];
        BYTE    type;
        void    *def;
        void    *var;
}
```

We might, therefore, pack the "var N" command as follows, assuming a '1' represents an integer type:

STX|v|a|r||0|n1|n2|n3|n4|n5|n6|n7|n8|1|d1|d2|i1|i2|ETX

- n1-n8 — The eight-byte name of the variable.
- d1-d2 — The default value.
- i1-i2 — The current value of the variable.

When we receive this packet, we can deconstruct it, see it's a variable and which one in the array, get the name and the two byte default and current integer values. If the variable was a floating point variable, the type might be a binary 2 and the default and current values would be four bytes long.

When the bot first transfers its complete param array, it will pack between one set of STX and ETX multiple "var N" messages, with each N identifying the variable's position in the array.

MANAGING THE MESSAGES

Both the bot and the console will be expecting specific commands at certain times. For example, when the console sends "send" to the bot, the console will be expecting a "var N" command from the bot in return.

This can be easily managed in one of two ways, both are very similar. The idea is to have a routine which — at a regular interval — checks to see if any serial data has come in. When it finds an STX, it unpacks all the data into a buffer until it finds an ETX and only then returns. So, we might say:

ret = waitForPacket(buffer, 30);

This routine would only return when it has compiled a packet into the buffer or after the time-out of 30 seconds has passed. This is fairly simple to implement and is probably sufficient for our needs, however, a version could be implemented which waits for a specific command, for example:

ret = waitForCommand(
"ready," buffer, 30);

SUMMARY

With this more complete set of tools, we can finish the implementation of the hand-held console. Next month, I will show the completed device, discuss how well it works, and go over any "would like to have's." Also, I should mention that A7 Engineering have just released a more generic EB module called the EB501 which is not dependent upon the AppMod and may be easier for me to use. If I have one of those by next month, I will talk about it. **NV**

RESOURCES

■ *Matrix Orbital LCD* — **www.matrixorbital.com**

■ *EmbeddedBlue* — **www.parallax.com**

■ *EmbeddedBlue* — **www.a7eng.com**

■ *FreeRTOS* — **www.freertos.org/**

■ *WinAVR* — **http://winavr.sourceforge.net/**

■ *AVRstudio* — **www.atmel.com/dyn/products/tools_card.asp?tool_id=2725**

■ *Rutherford Robotics can laser-cut the console for you* — **http://rutherford-robotics.com/laser.html**

■ *Parallax* — **www.parallax.com**

■ *Phil Davis* — ***phild2@charter.net***

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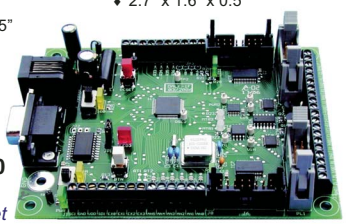

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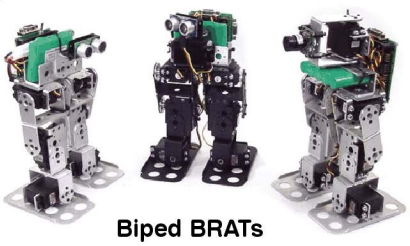

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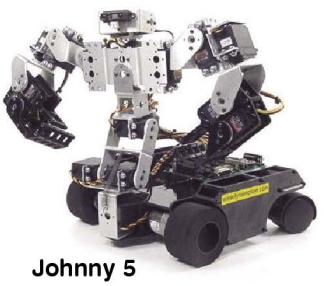
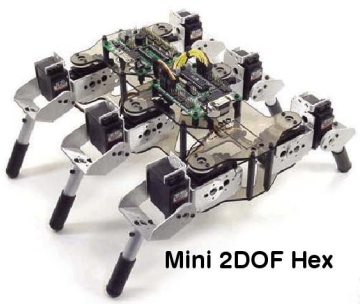
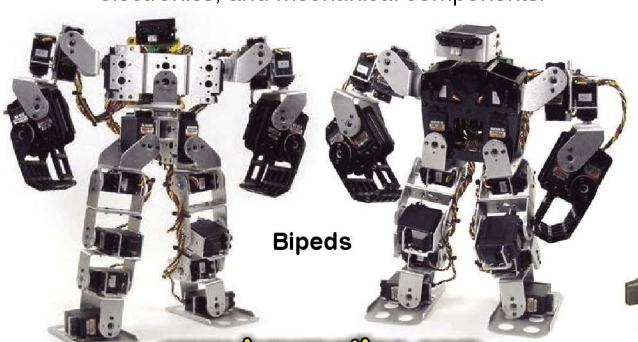


Johnny 5



Mini 2DOF Hex

Round 3DOF Hex



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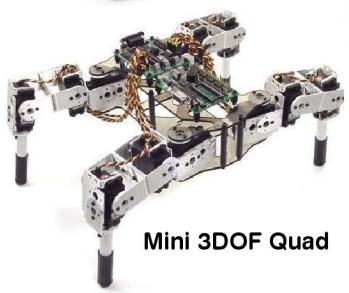

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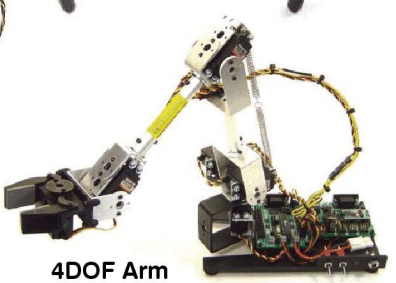

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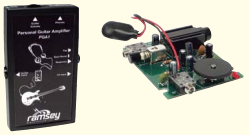

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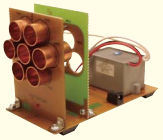

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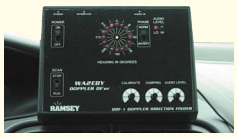

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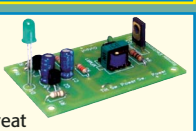

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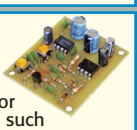

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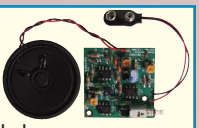

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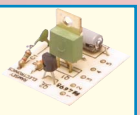

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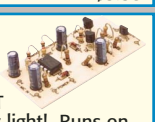

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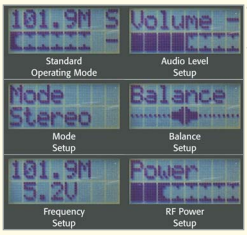

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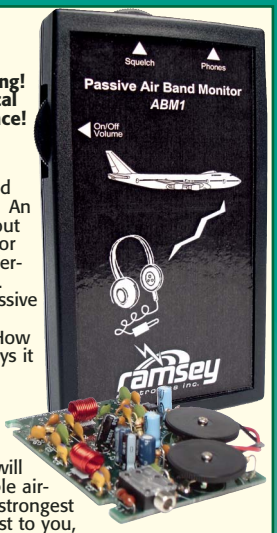

- ✔ **Monitors the entire aircraft band without tuning!**
- ✔ **Passive design, can be used on aircraft, no local oscillator, generates and creates no interference!**
- ✔ **Great for air shows**
- ✔ **Patented circuit and design!**

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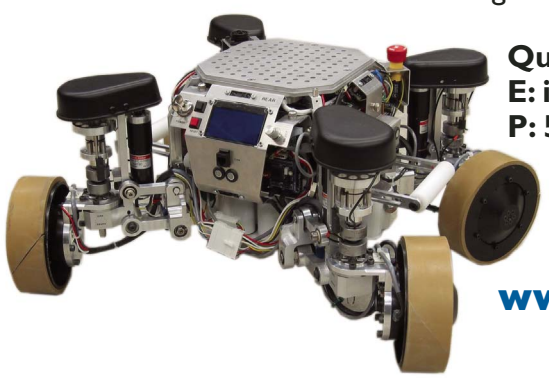

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PIC VS. PIC SPEED TEST

IF YOU LOOK THROUGH *NUTS & VOLTS* OR SURF THE INTERNET, you'll see lots of different Microchip PIC-based development chips and modules offering all kinds of different features. Some of the more popular ones are the PICAXE, BASIC Stamp, Basic Atom, and even my own Ultimate OEM and BasicBoard — just to name a few. Which is the best platform to start with or what is the best bang for the buck are topics of questions I often get in Email. Readers frequently ask how these compare to programming with a Basic compiler like PICBasic Pro. In this month's column, I'll compare them all with a common program to see how well they do against each other.

The Emails I often get come from readers of this column who are just getting started programming and have also read the BASIC Stamp column or have read about the PICAXE or read about the Basic Atom and wonder what the difference between all of them are. Because of all these choices, they begin to doubt their own instincts.

In their Emails, they might ask if the BASIC Stamp is really a Microchip PIC-based module since they read something about Scenix. Or, they read about the PICAXE and wonder why it doesn't need a hardware programmer. Then they read another book or article and it tells them only a "real compiler" is the way to go if they plan to take their design into production. They begin to question the advantage of PICBasic Pro over the single chip approach, such as PICAXE.

In most cases, the limiting factor comes down to cost. Let's face it, if money wasn't an issue you could own them all and evaluate them for yourself, but that's not often possible. Fortunately, I've collected several of these systems over the years because I was curious myself and decided to run my own tests.

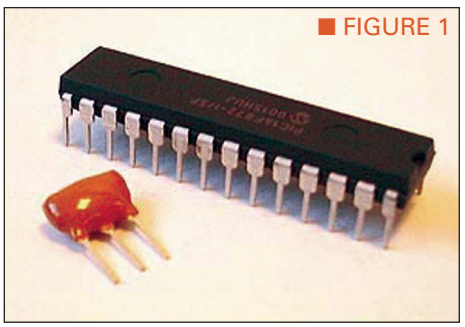
Back in the early days of computers, there was a speed test program I could run at the DOS prompt that would give me a performance rating on the PC. By comparing this rating, I could determine if one PC was really better than the next. I thought this would be a great way to compare PIC options because by measuring speed, you are also measuring code size. If it takes a long time on one module to process the same function that it does on another module, then it must use more PIC commands. No matter how the code is written, it eventually gets down to binary 1s and 0s.

I decided to reproduce that test to compare the various PIC-based setups. I've selected five popular hobbyist approaches: BASIC Stamp 2 (BS2), PICAXE 28x, Basic Atom 28, PICBasic, and PICBasic Pro. I'll also compare a popular "C" compiler for this test to see if programming in C is that much faster than Basic. For those that aren't familiar with these choices, I'll begin by briefly describing them.

PICAXE

I have to admit when these first came out, I wasn't impressed. They based their operation on the original BASIC Stamp 1 (BS1) PBasic command set, which is limited. The original BS1 was built around a PIC16C56 with an external EEPROM memory for storing the commands. The PICAXE (Figure 1) reduced those two chips into a single chip with software. I didn't see that as a big advantage, but on the other hand, I was impressed with the free PICAXE flowchart style GUI programming software. This made it easier for kids to get involved.

PICAXE also offers the ability to program directly in PBasic commands just like the BS1. I began to re-think my first impression. The PICAXE has since grown to include a whole variety of options and new commands



■ FIGURE 1

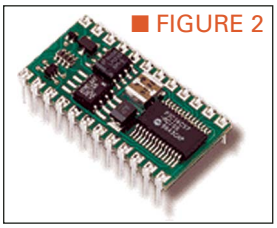


FIGURE 2

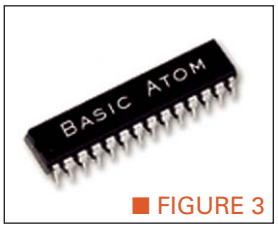


FIGURE 3

beyond the BS1. This all comes at a very low price as you can get PICAXE chips and starter kits for only a few dollars.

Every PICAXE is a Microchip PIC with a custom, self-programming software program installed. At first, I thought it was a bootloader but since some of the PICs they use don't offer self-write memory, I figured this wasn't the case. The small eight-pin version is based on a PIC12F629 and the 28x (that I'll use in my test) is based on a PIC16F873. The other versions are PICs, but I'm not sure which ones since I can't find details on them and I only have these two I've mentioned in my lab.

It's clear, though, that they work similar in that they program themselves through a serial connection. The BS1 operated the same way and stored command tokens in external EEPROM. My guess is the PICAXE stores command tokens in internal EEPROM and then retrieves each command one at a time and processes it. Therefore, when you program a PICAXE, you are passing tokens to it that get stored in EEPROM by the resident software already on the chip.

Each PICAXE chip has a limited number of total commands with the maximum being 600. This seems to relatively match the EEPROM size of the particular package size. The eight-pin has a smaller EEPROM and smaller command limit and the larger PICs have more EEPROM and larger command limits. What I questioned most was the speed. The PICAXE 28x runs with an external 4 MHz resonator and I suspect the eight-pin PICAXE and the others run on the internal 4 MHz RC oscillator that these PICs have.

I know the BS1 also ran at 4 MHz and that PICBasic-compiled BS1 programs ran faster than they did on the BS1, so I was very curious how fast the PICAXE ran. Let's cover the other players before that.

BASIC STAMP 2

The BS2 (shown in Figure 2) was a great module when it was first released. It was one of the first PIC-based modules for those that wanted to use the easy-to-understand Basic language to program PICs. The BS2 also has a free programming software that is command based, so all you need is a BS2 module (or you can build one from the BS2 interpreter chip and EEPROM). The interpreter chip is more money than a PICAXE chip, but I suspect it would run faster than the PICAXE. The BS2 advertises 4,000 instructions per second while the BS1 is only 2,000 instructions per second. The BS2 also runs on a 20 MHz resonator versus the PICAXE and BS1 at 4 MHz.

The BS2 is based on a PIC16C57 and also stores command tokens in external EEPROM. The access time to read and write to external EEPROM is slower than writing to internal EEPROM on a PIC, so that will affect processing speed during my test. I began to wonder if the PICAXE with internal EEPROM would be as fast or faster than the BS2, even though the BS2 has the faster oscillator.

BASIC ATOM

The Basic Atom (Figure 3) takes the PICAXE/BASIC Stamp programming style a little further in that it pseudo compiles or combines the token-style commands with the processing routines and stores them in a binary .hex file. This binary .hex file gets programmed into the PIC's program memory. This way, the program is retrieving information from within program memory rather than EEPROM memory. This is much faster than EEPROM access but uses a lot of program memory initially when it downloads all this to the PIC.

The Atom is based on the PIC16F876A and 16F877A both of which have the capability to self-write to program memory from within the software. This is how a bootloader works and a bootloader is how the Atom programs itself through a PC serial connection. This is why an Atom doesn't need a separate PIC programmer — similar to PICAXE and BS2 — to download the .hex file it creates.

PICBASIC

PICBasic (Figure 4) is the original Basic compiler frommicroEngineering Labs and it takes BS1 programs and directly converts them into an assem-

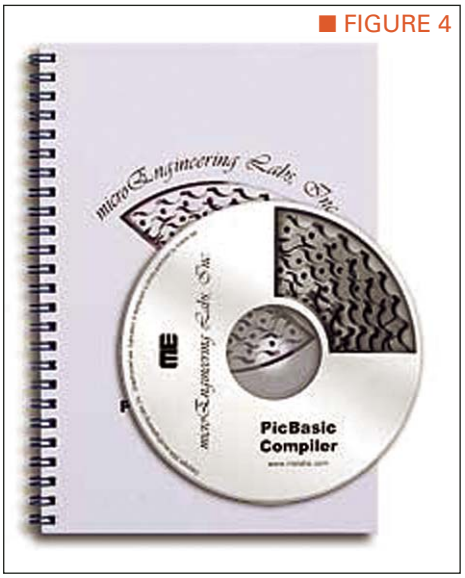


FIGURE 4

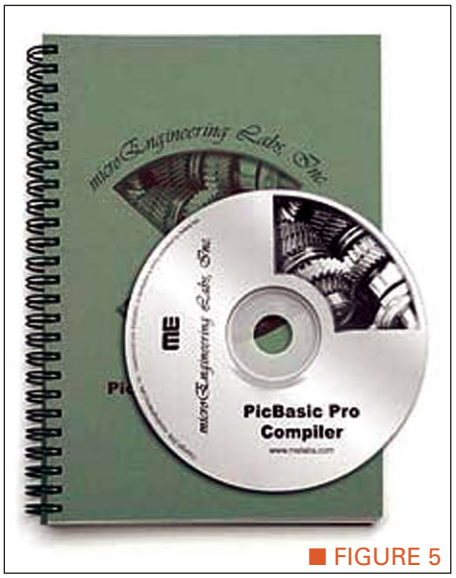
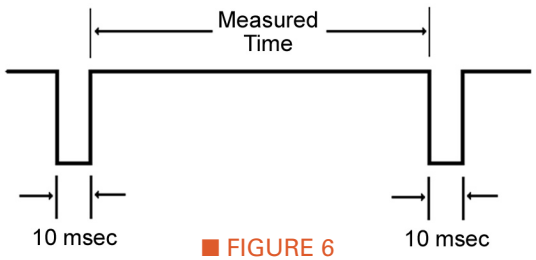


FIGURE 5



■ FIGURE 6

PIC Option	Measured Time
PICAXE 28x @ 4 MHz	368 msec
BASIC Stamp 2 @ 20 MHz	278 msec
Basic Atom @ 20 MHz	68 msec
PICBasic in PIC16F876A @ 4 MHz	28 msec
PICBasic Pro in PIC16F876A @ 4 MHz	1.76 msec
PICBasic Pro in PIC16F876A @ 20 MHz	0.350 msec

■TABLE 1

bly language file that gets assembled into a true binary .hex file. This .hex file can then be programmed into a blank PIC with a hardware PIC programmer. This is the compiler that got me started programming blank PICs in Basic.

I had reached a limit with the BS1 and had moved on to the BS2 when PICBasic arrived on the scene. Programming in assembly language just was too time-consuming for me. I was amazed at how easy it was to program off-the-shelf PICs. The PICAXE and Atom weren't around when the PICBasic compiler was introduced, so those weren't an option.

The PICBasic compiler added a few commands to the BS1 PBasic command set that allowed it to access registers in the PIC and it also allowed more RAM space to be used for variables.This was a huge advantage over BS1 and BS2. PICBasic was the best thing going until the PICBasic Pro compiler was released. PICBasic is limited to 2K of PIC program memory so even if you have an 8K PIC, you would have to do some special coding to get beyond 2K. I thought it was interesting to add PICBasic to my performance test since I haven't used it in a while and haven't even talked about it in this column series. I do include both PICBasic and PICBasic Pro in my book *Programming PIC Microcontrollers with PICBasic*, though.

At $99.95, PICBasic is a pretty good alternative to programming with PICAXE or BS1 since the commands are the same and you can use it with blank PICs. PICBasic is also written to run programs at 4 MHz. You can run the PIC faster, but some of the time-critical commands will be affected. For example, a PAUSE 1000 will delay one second at 4 MHz, but run the PIC at 20 MHz, and that command will only take 200 milliseconds. Some people use this method to get higher baud rates out of PICBasic's SEROUT command. For the performance test, I ran it at 4 MHz.

PICBASIC PRO

The PICBasic Pro compiler (Figure 5) has been talked about a lot in this column. It added so many features to the PICBasic compiler, it clearly was in a class by itself when it was released, and is still one of the more popular compilers on the market. The PICBasic Pro compiler produces an assembly file that gets assembled into a binary .hex file so it can program just about any eight-bit PIC out there. I noticed right away when I switched from PICBasic to PICBasic Pro that it greatly reduced the memory size of my programs in the exact same PIC.

PICBasic Pro isn't limited to 2K like PICBasic, so its number of commands is only limited by the program memory space of the PIC you are using. If you use a PIC18F6722, you get 128K bytes of program space. I rarely use more than 8K, so that's one huge advantage of PICBasic Pro. How much better it is at speed is really the question I want to answer. PICBasic Pro can be set up to run at various speeds with a simple DEFINE insert, so this allowed me to run the same program at both 4 MHz and 20 MHz.

SPEED TEST

Now for the moment we've all been waiting for — the speed/performance test. I wanted to create a simple program that could be used across all these different platforms with very little or no modification. I knew I wanted it to process several commands in a loop and also perform some math. I wanted to light an LED so I could see it working and be able to put an oscilloscope on the LED to measure the time it took to change state. This change in state delay reflects the processing time, so by recording that time, I could compare everything running the exact same Basic code. The final program is below:

C Code

```
while(1==1)      //loop forever
{
       unsigned int z, y;
       RB0 = 1;     // Turn on RC0 LED
       for(z=0; z<256; z=z+1)
       {
       y=y+1;
       }
       RB0 = 0;     //Turn off RC0 LED
       Pause(10);   // Pause 10 msec

}      //End while
```

PICBasic Pro Code

```
Main:
high 1       'Set Port 1 High to Light LED
For x = 1 to 255
y=y+1        ' Perform simple math
next
low 1        'Clear port 1 to turn off LED
pause 10     'Stay low for 10 milliseconds

goto main
```

■TABLE 2

Compiler	Measured Time
PICC-Lite in PIC16F877A @ 4 MHz	3.6 msec
PICBasic Pro in PIC16F876A @ 4 MHz	1.76 msec

■TABLE 3

```
Main:
    high 1              'Set Port 1 High to Light LED
    For x = 1 to 255    'Loop 255 times in for-next loop
    y = y + 1           'Perform simple math
    next                'End for-next loop
    low 1               'Clear port 1 to turn off LED
    pause 10            'Stay low for 10 milliseconds
goto main
```

On each part I had to create the x and y variables in slightly different ways. In PICAXE and PICBasic, I used:

```
Symbol x = B0
Symbol y = B1
```

On the others, I used the VAR directive:

```
x var byte
y var byte
```

These variable declarations didn't affect the speed since they are a one-time function. I was really surprised how easy it was to make one program fit all these different platforms, which shows how common the Basic language is for PICs. Each processor reported a different amount of program space and I was a little confused on how to measure some of them. I could not figure out how much memory I used in the BS2, but I'm sure that was because of my inexperience with the Stamp programming environment. For the most part though, program size affected speed. The slower the class of chip, the more memory it used.

RESULTS

The chart in Table 1 and graphic in Figure 6 show the results. The PICAXE came in the slowest and PICBasic Pro (at 20 MHz) was the fastest. That is, over 1,000 times faster. You can also see how the move from external EEPROM to internal program memory helped the Atom beat out the Stamp. I was surprised to see PICBasic Pro at 4 MHz beat PICBasic. The Pro program was about one-third the size of the PICBasic program.

C VS. PICBASIC PRO

I often get Emails from C programmers asking me to stop using that interpreted Basic code and program in C. PICBasic Pro really is compiled just like C and, in many cases, will produce code the same size as a C language compiler.

I decided to write the "Basic" program in C using the HiTech PICC-Lite compiler from **htsoft.com**. This is a popular PIC C compiler and I like it a lot. I will not claim to be a great C programmer, but the results of this test were very interesting. The speed test code in C is below:

```
unsigned int counter;    // Create delay loop variable
                         // with max range of 0 to 65535

// Prototyping functions
void Pause( unsigned short usvalue );
void msecbase( void );

main()
{
        PORTB = 0;       //Clear PortC port
        TRISB = 0;       //All PortC I/O outputs

        while(1==1) {            //loop forever
                unsigned int z, y;
                RB0 = 1;         // Turn on RC0 LED
                for(z=0,y=0; z<256; z=z+1) {
                        y=y+1;
                }
                RB0 = 0;         // Turn off RC0 LED
                Pause(10);       // Pause 10 msec
        }      //End while
}     //end main
//*******************************************************
//pause - multiple millisecond delay routine
//*******************************************************

void Pause( unsigned short usvalue )
{
unsigned short x;

//Loop through a delay equal to usvalue in ms
        for (x=0; x<=usvalue; x++) {
                msecbase();       // ms delay routine
        }
}


//*******************************************************
//msecbase - 1 msec pause routine
//*******************************************************

void msecbase(void)
{

//Set prescaler to TMRO 1:4
    OPTION = 0b00000001;
    TMR0 = 0xd;   // Set TMR0 to overflow on 250
    while(!T0IF); //Stay until TMRO overflow flag set
    T0IF = 0;     //Clear the TMR0 overflow flag
}
```

This will look very confusing to beginners and Basic programmers since C is very cryptic at first glance. If you compare the core section of both versions, you will see a lot of similarities, however, as shown in Table 2.

I then compiled the C code and ran it at 4 MHz to compare it to the rest of the pack. The results in Table 3 show how PICBasic Pro at 4 MHz compares to PICC-Lite at 4 MHz.

I have to admit I was shocked by these results. I may have screwed up somewhere, but I tested it on

several PICs after this and got the same results. PICBasic Pro was faster than C in this simple application. To further understand the results, I reviewed the .hex files and saw that PICBasic Pro compressed the code into a single block of space that took up 60 words of program memory.

The PICC-Lite version broke up the code into two blocks: one at the top of program memory and one much further down. This told me that PICC-Lite had produced code that possibly jumped around more than PICBasic Pro. If your assembly code has more calls or gotos in it, then it will take more time to process. The PICC-Lite file took 68 words of space. This was larger than PicBasic Pro.

PICC-Lite is a freeware version and doesn't have all the optimization layers in place that help compact the code, so there are improvements that can be made. Compacting can sometimes add more calls, so I'm not sure that would help. Inserting assembly into C helps speed things up, but you can do that in PICBasic Pro, as well. All in all,I was impressed at how well PICBasic Pro performed against PICC-Lite in this test.

If you want to become a professional software engineer, then C is still the most desired language to know. However, PICBasic Pro can compete well in applications where you may need to rely on a simple Basic language to get a product out the door quickly. I've helped many non-software engineers do this using PICBasic Pro.

CONCLUSION

Based on this brief study, I've concluded that no matter how you get started, you end up getting what you pay for. If you only have a few bucks, then PICAXE is a great place to start and you will learn the language that can later be used with PICBasic Pro. Basic Atoms and Stamps offer a smooth upgrade path to PICAXE and PICBasic/PICBasic Pro offer the ultimate option for programming low-cost PICs.

Purchasing a decent PIC programmer and PICBasic Pro will cost a few hundred dollars, but divide that up among all the projects you create with it and it will bring the cost down. Once you start reading sensors or trying to process large amounts of data, speed becomes a priceless advantage. I still do a lot of work with Atoms because of the great built-in, in-circuit debugger (ICD) and I like some of the commands it offers that PICBasic Pro doesn't.

I hope you've learned something that will help you decide the best route to take getting started. If you have any questions or comments, send them to me at chuck@elproducts.com or visit my website at **www.elproducts.com** for all your "Programming PICs in Basic" needs. See you next month. **NV**

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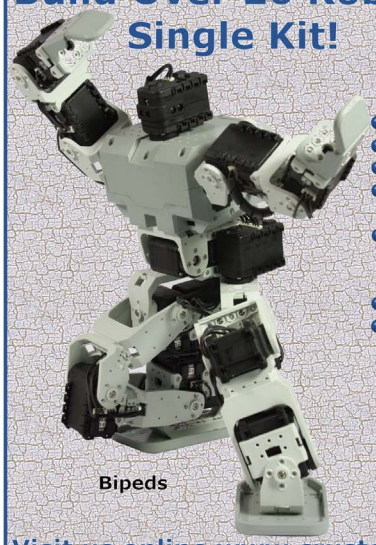

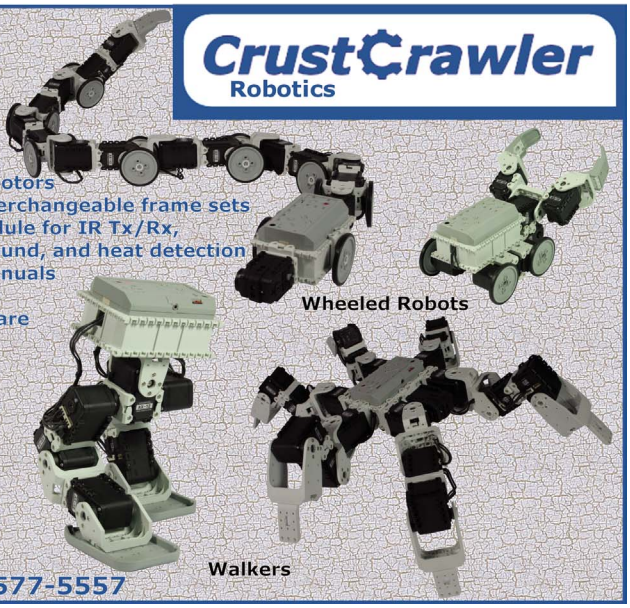

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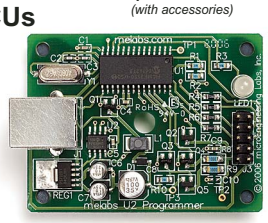

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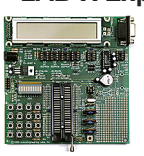

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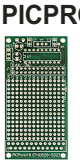

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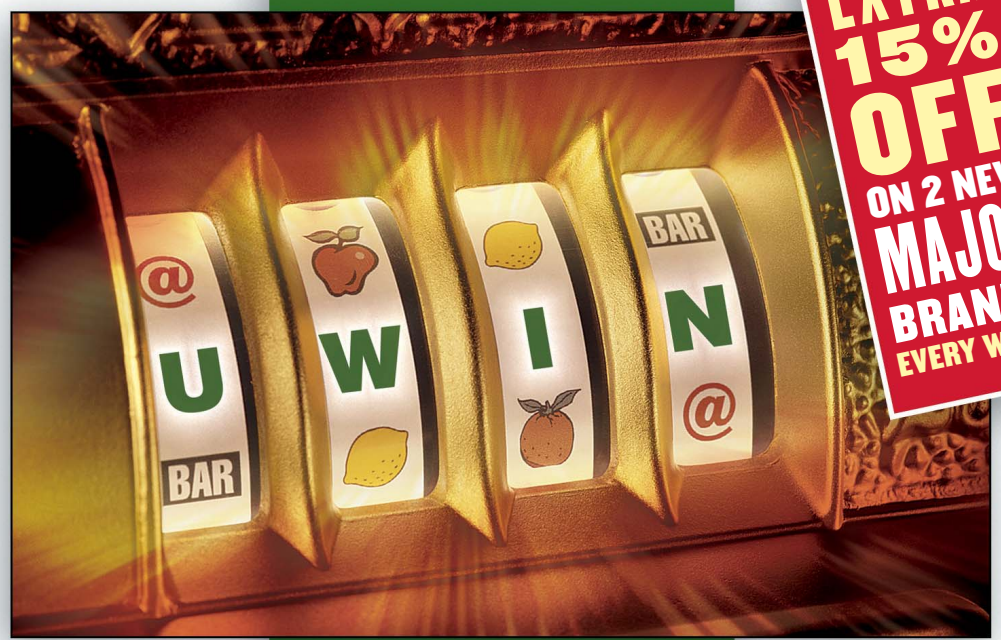

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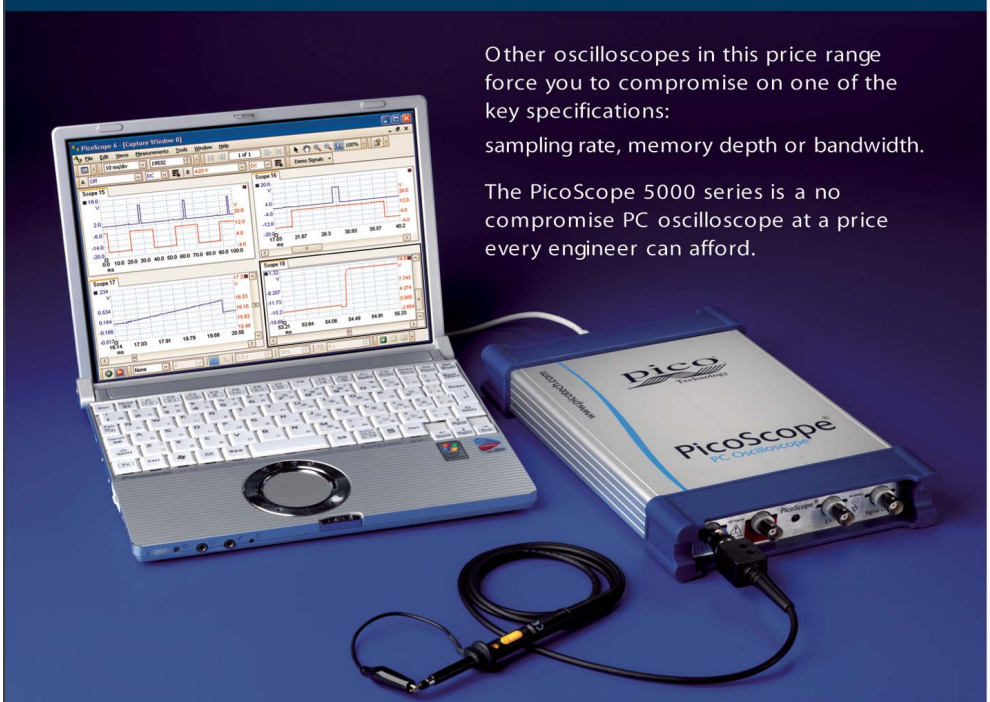

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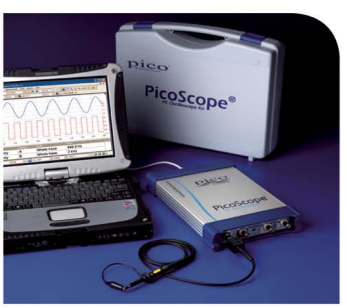

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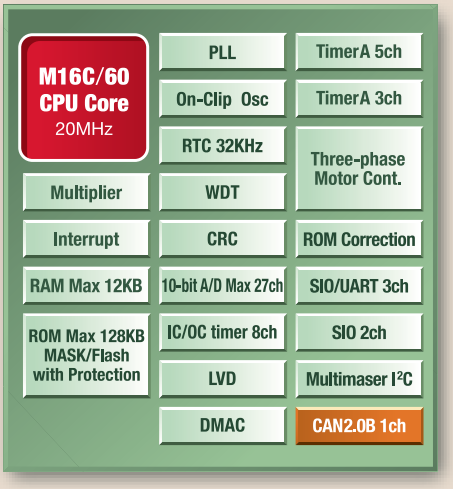
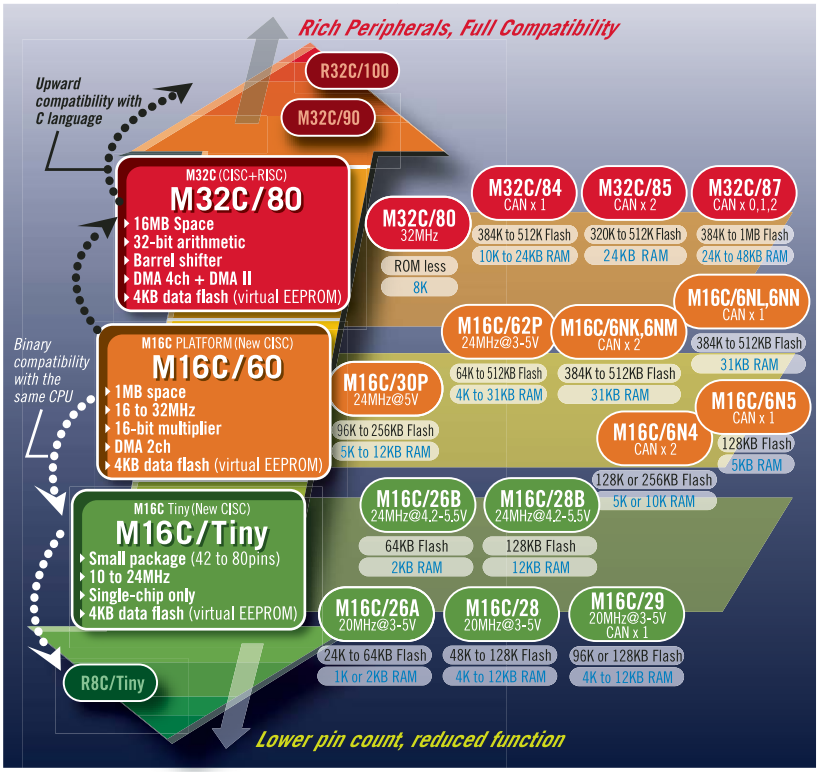


M16C Product Roadmap



*Source:Gartner Dataquest (April 2006) "2005 Worldwide Microcontroller Vendor Revenue" GJ06333

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Utilizing reverse pulse plating (RPP) technology allows uniform metal distribution for more aggressive aspect ratios. The MiniContac RS has the ability to plate holes as small as 8 mil (0.2 mm) vias in 62 mil thick standard PCBs smoothly; thin or fragile materials can easily be placed in a support framework before processing. The MiniContac RS handles circuit boards as large as 9" x 13" (230 mm x 330 mm) and is completely closed with no external connection needed, allowing double-sided and multilayer boards to quickly and easily be through-hole plated. North American Vice President Jim Greene stated, "The MiniContac is simple and easy to operate. It uses safe chemicals to make plated through-holes and does not require special operation skills. This system takes advantage of the reverse pulse plate technology, for a clean, perfect through-hole plating process."

The MiniContac RS uses only four tanks, which can easily be replaced when required. For ease of use, LPKF handles the complete disposal of all plating chemicals. This system features LPKF's standard approach to prototype plating solutions, favoring simple maintenance of chemical assets, and a semi-automated menu-driven control system.

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DO-IT-YOURSELF LIQUID COOLING FOR PC HOBBYISTS OVERCLOCKING MULTI-CORE PROCESSORS

D-Tek Customs, an innovator of top-performing heat-dissipation products for computer gamers, overclockers and case modders, has begun volume shipments of its FuZion CPU block, a liquid cooler optimized for the latest dual- and quad-core processors from Intel Corp. and Advanced Micro Devices (AMD).

The D-Tek FuZion CPU block's advantage is a unique base plate that delivers more efficient thermal control than existing water blocks. Specifically, the FuZion CPU block uses an impingement design that puts liquid directly in the middle of the processor, where the cores are located. The copper base plate — with its dense rounded copper pins and 1.4 square-inch pin spread especially designed for large-die, multi-core processors — increases theFuZion CPU block's cooling surface area.

Unlike other high-performance impingement water blocks that require expensive high-flow pumps — with the bigger size and louder operation associated with those pumps — the FuZion CPU block achieves a vastly lower pressure drop (three to five times lower). As a result, it can deliver high-performance thermal management in a smaller, quieter, more cost-effective package. Additionally, the FuZion CPU block's 4-to-1 flow chamber provides optimal flow through the block.

"Our low-pressure-drop FuZion CPU block provides gamers with the best thermal performance without the large, noisy, expensive pumps that are typically needed in liquid-cooled gaming PCs," said Danny Salandra, D-Tek's chief executive officer.

With less load on the pump, a cooling system based on the D-Tek FuZion CPU block has a longer life cycle — even under vigorous operating conditions.

"In addition, the low-pressure-drop, high-performance FuZion block is ideal for multi-block solutions that include single and multiple GPU block configurations, while still using only one pump per system," Salandra said.

D-Tek paid careful attention to the manufacturability of the FuZion CPU block, exerting exceptional quality control — including leak-testing each part and ensuring consistent manufacturing from one block to the next. Its 100-percent-copper base is machine-lapped to a precise finish, and its top assembly is molded Delrin/Acetal.

Price and Availability

The D-Tek FuZion CPU block — the first in a series — is available now through D-Tek's worldwide reseller partners. The list price is $64.99, which includes all necessary mounting hardware for both AMD and Intel processors.

Coming soon is a nozzle jet impingement kit that will take advantage of the low-pressure-drop design and increase the water velocity directly on top of the multi-core processors.

The company has its headquarters

in Murrieta, CA, near San Diego.

For more information, contact:
D-Tek Customs
Web: **www.dtekcustoms.com**

EMBEDDED COLOR VGA GRAPHICS

Multilabs announces the release of their first custom controller chip called the ezVGA Graphics Controller, and their newest "ez" serial-controlled embedded module called the ezVGA Serial Module.

ezVGA Graphics Controller

The ezVGA Graphics Controller is an embedded color VGA processor that can be used to generate VGA signals for image display on VGA monitors and VGA compatible devices. Using the data instructions, the host writes and reads pixel color data through the ezVGA Graphics Controller to the external video memory. All operations are done automatically via the on-board circuitry. Sync signals, video memory pixel reading and writing, continuous screen drawing, pixel counts, and line counts are all done automatically through the ezVGA Graphics Controller. The host only needs to know six simple instructions for complete operation. Communications to and from the ezVGA Graphics Controller is done through an eight-bit data bus along with four address control lines. Having addressable control lines allows the ezVGA Graphics Controller to share a common system data bus with other devices. The ezVGA Graphics Controller offers a fast parallel interface and pixel read/write times of only 40–120 nanoseconds.

The host creates texts and graphics by writing pixels to the screen. The screen pixel color data is stored in an external video memory. This memory is automatically controlled by the ezVGA Graphics Controller and the host does not have to directly manage it. In fact, the ezVGA Graphics Controller handles all operations automatically so no knowledge of the VGA specification is necessary.

Besides writing pixels, the host can also read any pixel on the screen. All of this is done (again) via six simple instructions that allow the host to set the X position, Y position, pixel color, and issue pixel write and read commands. Other features such as auto-incrementing the position registers allows the host to perform fast writes and reads of the entire screen.

The ezVGA Graphics Controller comes housed in an 84 pin PLCC package that conforms to JEDEC MO-047. The ezVGA Graphics Controller can be purchased by itself for $24.95 (single piece price). It can also be purchased with a video memory chip for $29.95 (single piece price). The video memory comes in a 32 pin TSOP II package. Quantity pricing is available.

ezVGA Serial Module

The ezVGA Serial Module is a ready-to-use embedded color VGA video card that will deliver color VGA video functionality to your design. The ezVGA Serial Module takes away the problem of needing an enormous amount of I/O pins and lots of processing power typical for high resolution color VGA video generation and replaces it with only two serial communication pins and simple to learn and use commands. The ezVGA Serial Module offers a quick and cost-effective way to generate color VGA text and graphics.

Everything you need to get started quickly is housed on a 2.5″ by 3.1″ SIP module, even right down to the VGA monitor connector. Commands are sent and status received via a TTL level two-line serial asynchronous interface. The command set gives you the ability to clear areas of the screen, change the background color, clear the entire screen, define custom characters, use a floating character which can be used for a point-and-click interface, draw lines, place characters, and read pixels from and write pixels to the screen. The floating character can be displayed and moved around anywhere on the screen without disturbing any of the image on the screen. This adds another level of character display.

The screen resolution is 320 by 240 pixels and there are 64 colors to choose from. The ezVGA Serial Module comes with a built-in ASCII character set and gives you the ability to define up to 256 characters. You can also change the built-in character set to fit your needs. The screen is layed out as a bitmap. This means there are no character cells which gives you the freedom to place characters wherever you need. This gives the ezVGA Serial Module the flexibility to meet any of your design needs.

You can connect the ezVGA Serial Module to any VGA video device.

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THE ENERGYSAVER

Nevvus Corporation announces the launch of their Nevvus Energy Saver, an innovative new product that reduces power consumption in homes by up to 10% and more. The Energy Saver reduces the amount of power drawn from the utility company by storing (in capacitors) otherwise lost electricity caused by inductive motors in home appliances (examples of inductive motors are air conditioning units, refrigerators, dishwashers, vacuum cleaners, fans, etc.).

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SWEEP FUNCTION GENERATOR

B&K Precision Corporation announces the availability of the Model 4017B, a 10 MHz DDS sweep function generator that utilizes Direct Digital Synthesis (DDS) to generate very precise and accurate waveforms with little distortion. At a price of only $499, the new Model 4017B is extremely flexible, and has a vast number of applications in both analog and digital electronics in the engineering, manufacturing, servicing, educational, and hobbyist fields.

The B&K Precision Model 4017B 10MHz DDS sweep function generator is a versatile signal source which combines several functions into one unit — waveform generation, pulse generation (through variable symmetry), and frequency sweep. Additionally, the instrument provides the added convenience of a built-in frequency counter. Utilizing DDS technology to produce precise and accurate waveforms, the unit permits more accurate determination of output frequency than is possible with a simple calibrated dial. Coarse and fine tuning controls permit the precision setting of the output frequency.

The heart of the function generator is a VCG (voltage controlled generator) that produces precision sine, square, or triangle waves over the 0.1 Hz to 10 MHz range. This encompasses sub audible, audio, ultrasonic, and RF applications. A continuously variable DC offset allows the output to be injected directly into circuits at the correct bias level.

The sweep generator offers linear or log sweep with variable sweep rate and adjustable sweep time. Variable symmetry of the output waveform converts the instrument to a pulse generator capable of generating rectangular waves or pulses, ramp or sawtooth waves, and slewed sine waves.

In addition to the above features, an external voltage may be used to control operating frequency. This is useful in situations where an externally controlled frequency is desirable. The unit comes with a user instruction manual and B&K Precision Corporation's one-year warranty.

For more information, contact:
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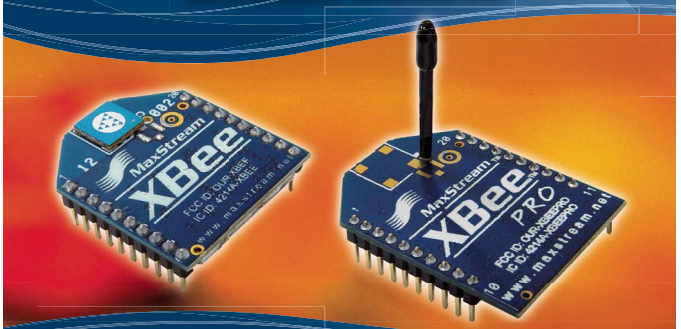

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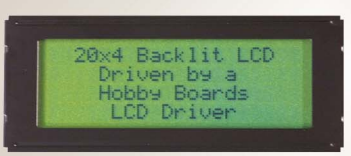

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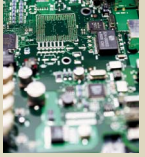


THIS MONTH'S PROJECTS

An X-10 Interface 32
Pulse Speed Timer 39
The Magic Box 48

LEVEL RATING SYSTEM

To find out the level of difficulty for each of these projects, turn to our ratings for the answers.

●○○○ . . . . Beginner Level
●●○○ . . . . Intermediate Level
●●●○ . . . . Advanced Level
●●●● . . . . Professional Level

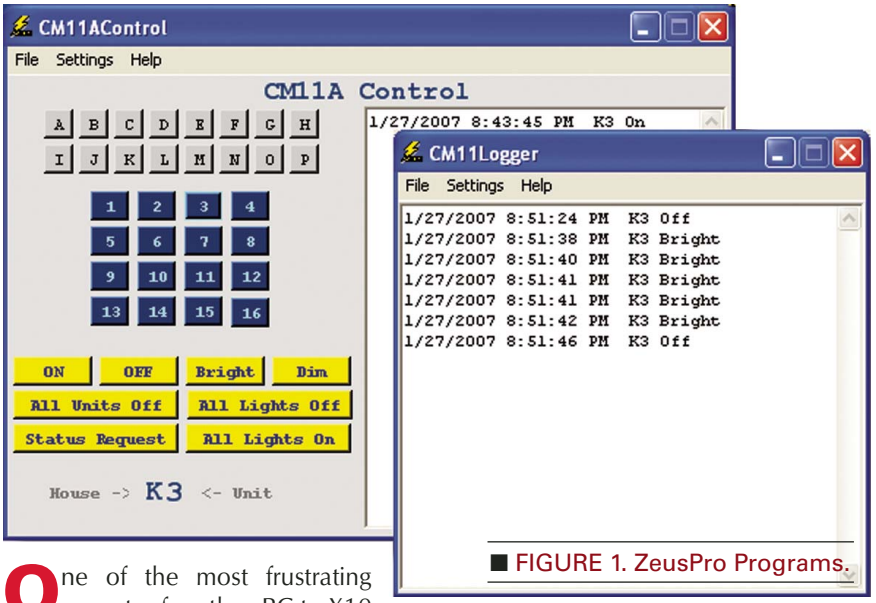
Last month, we looked at interfacing your PC to various 1-Wire weather sensors.

This month, we are going to dive head-first into home automation.

I am going to show you how to use your PC to control lamps and appliances using the X10 protocol.

CONTROL YOUR WORLD WITH AN X-10 INTERFACE

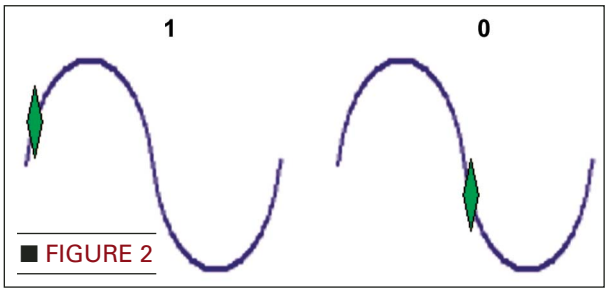
Home Automation



■ FIGURE 1. ZeusPro Programs.

One of the most frustrating aspects for the PC-to-X10 interface is lack of quality documentation. For an industry that has so much demand, you would think that the manufacturers would create some quality manuals explaining in detail the protocol that their devices require. This is just not the case. The instructions for the various interface devices I tested went from nonexistent to poor. Most of the technical information I managed to get my hands on was after many hours of searching the net. In many cases, I had to use a lot of guesswork to get the interfaces to work.

I will show you how to use three different RS-232 interfaces. We will be looking at the FireCracker (CM17A), SmartHome PowerLinc (1132B), and the RCA ActiveHome (CM11A).



■ FIGURE 2

How Does X10 Work?

It isn't necessary to know how the X10 protocol is transmitted over the power

lines, but a brief overview may help you to troubleshoot problems. X10 uses a PLC technology, which stands for Power Line Carrier. A 1 ms, 120 kHz burst is transmitted near the zero crossing of the 60 Hz AC signal. Two crossings are required to form a single bit. To generate "1," we need a burst at the first crossing and none at the second, as shown in Figure 2. Figure 2 also shows the pattern is reversed for "0;" we need a burst at the second crossing but not the first. Things would get out of sync very fast if we did not have some way of starting the whole data packet. A special start sequence is used. This sequence is three 120 kHz bursts at consecutive crossings followed by no pulse, as shown in Figure 3.

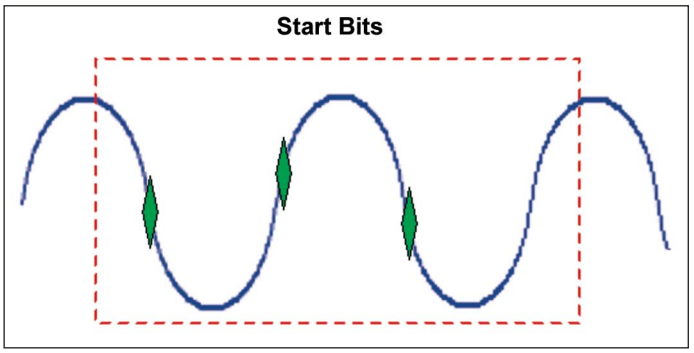
After the start sequence, the next nine bits represent the actual data being transmitted. The first four bits are the house code. The house codes are represented by letters on the actual devices to make it easier on the consumer as in Table 1.

After the house code, the next five bits represent the device code or function to perform as shown in Table 2. The last bit is actually used to indicate that the device is to perform a function if the bit is 1. The complete message from start to finish is sent twice for redundancy.

In reality, there are variations to the above protocol such as sending extended data, but I won't be getting into these in this article. Let's start to break down the various RS-232 interfaces. Each has its own protocol and will translate your interface data into the X10 protocol I just talked about. It isn't necessary that you understand the actual details of the X10 protocol, just that you know how the House, Devices, and Function codes are laid out.

All the previous examples show a single pulse that is synchronized with the zero crossing. In reality, the X10 specification calls for three pulses to be transmitted to make the X10 compatible with a three-phase distribution system. The second pulse is sent 2.778 ms after the zero crossing. The third pulse is sent 5.556 ms after the zero crossing.

■ FIGURE 3



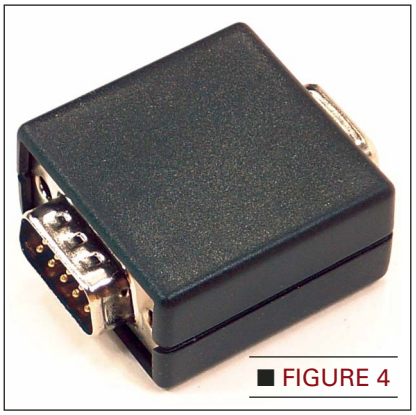
FireCracker (Model CM17A)

Let's start by looking at the FireCracker (Figure 4). Due to its price and simplicity, and the fact that it has been around for a long time, there are many of these in use today. The FireCracker is manufactured by X10 and can be purchased as an individual module or as part of the CM18A package. The cost for the CM17A will run you $12 to $40, depending on where you purchase it.

The CM18A package shown in Figure 5 is priced in the range of $22 to $39 and consists of the following modules:

- FireCracker Module (CM17A)
- Transceiver Module (TM751)
- Lamp Module (LM465)
- PalmPad Remote Control (HR12A)

I recommend the CM18A kit if you don't already have a wireless



■ FIGURE 4

A	0110
B	1110
C	0010
D	1010
E	0001
F	1001
G	0101
H	1101
I	0111
J	1111
K	0011
L	1011
M	0000
N	1000
O	0100
P	1100

■ TABLE 1

1	01100
2	11100
3	00100
4	10100
5	00010
6	10010
7	01010
8	11010
9	01110
10	11110
11	00110
12	10110
13	00000
14	10000
15	01000
16	11000
All Units Off	00001
All Lights On	00011
On	00101
Off	00111
Dim	01001
Bright	01011
All Lights Off	01101
Extended Code	01111
Hail Request	10001
Hail Acknowledge	10011
Preset Dim	101-1
Extended Data	11001
Status On	11011
Status Off	11101
Status Request	11111

■ TABLE 2

■ FIGURE 5

transceiver. You must have one for the FireCracker to operate. You can purchase the CM18A from **X10.com**, but I found the website very difficult to navigate due to the overwhelming amount of popups and crazy flashing adds. I purchased a brand new CM18A package from one of the eBay online stores. The cost was only $22 and I received it in just three days.

The FireCracker is a small and compact module. Since it's wireless and gets its power from the RS-232 signal, you can use it in portable interfaces such as a microcontroller or a Pocket PC. The only downside is that it's a one-way module. It transmits only, so it cannot receive data from sensors or other controllers.

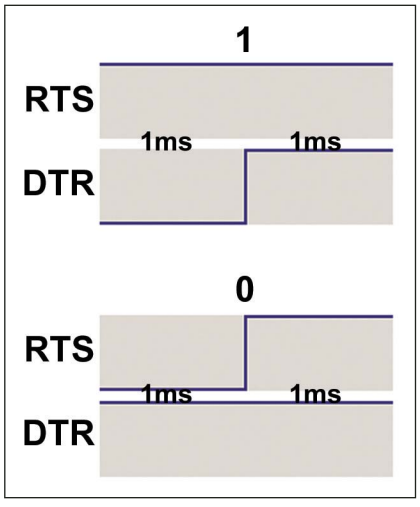
A	0110
B	0111
C	0100
D	0101
E	1000
F	1001
G	1010
H	1011
I	1110
J	1111
K	1100
L	1101
M	0000
N	0001
O	0010
P	0011

■ TABLE 3

The FireCracker uses a standard DB9 connector with an RS-232 interface. When I first started researching the FireCracker, I had assumed that the TX and Ground lead on the DB-9 connector were used at some predetermined baud rate. This is not the case. The FireCracker uses a two-pin binary interface. The RTS and DTR leads are used to power and to clock-in the data.

To send a 1, RTS is high and DTR is low, as shown in Figure 6. For a 0, DTR is high and RTS is low. Once signals are set, the system should wait for 500-1,000 µs then set both RTS and DTR high. The sequence is repeated eight times for a complete byte.

■ FIGURE 6



To send a complete control signal to the FireCracker, you need to send a sequence of 40 bits. This sequence consists of a header of 16 bits, data consisting of 16 bits, and a footer of eight bits.

The header is always 11010101 10101010 and the footer is always 10101101. As you might expect it's the 16 bits of data that tell the transceiver module what to send to the remote X10 devices.

Now, you would expect the data portion of the FireCracker protocol to match that of the X10. Well it doesn't. Take a look at Table 3. The house code bits are in reverse order.

If you look at Table 4, you can see that there is a pattern to the code/function sequence but it's not simple, so I just took the strong arm approach and listed all the combinations. In the downloads, there is a Zeus file called **FCm1.txt**. This program has support functions called: **SendX17Afooter**, **SendX17Aheader**, and **SendX17Adata**. The **SendX17Adata** makes a call to the header and footer functions so you need not worry about them. You simply pass the house code from Table 3 and the device/function code from Table 4.

Here is an excerpt of the main loop in the FCm1.txt program. It will turn on Device K1, then wait five seconds and then turn it off again. The FCm1.txt program is very simple and will compile and run in the free ZeusLite compiler available on the KRMicros website.

```
Loop:

  SendX17Adata(%1100, %000000000000)
  pause(5000)
  SendX17Adata(%1100, %000000100000)
  pause(5000)

  goto Loop
```

The **SendX17Adata** function will print the 1s and 0s as they are sent to the FireCracker so you can see what's happening.

Going Further with the FireCracker

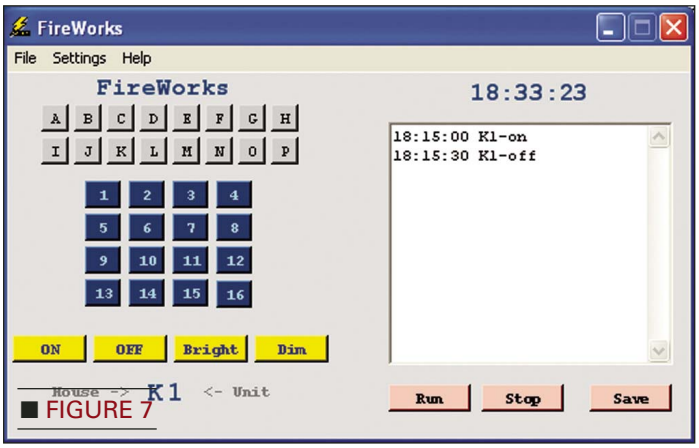
I have given you the basics for interfacing to the FireCracker. The next logical step is to create a more intuitive program to allow you to pass actual strings like K1on or K1off. I have included a ZeusPro source file called **FireCracker1Pro.txt** as an example of how to get started.

I have also included a couple of programs called FireCracker2Pro and FireCracker3Pro that will allow you to use a small form to send codes to your

Brief X10 History

■ Back in 1975, a company called Pico Electronics developed technology for what is now the X10 interface. It gets its name from the fact that it was the 10th project that Pico had created. The technology did not reach the market until 1978 when RadioShack started to sell X10 products. Sears then started selling X10 merchandise

Pico formed a partnership with BSR and X10 Ltd. was born. X10 Ltd. bought out BSR's interest in 1987. The X10 Patent expired in 1997 and now X10 is an open standard.



■ FIGURE 7

■ FIGURE 8

FireCracker. Both the source and compiled exes for Windows, as well as the Pocket PC exe, are included in the download.

Last, but not least, is a program I call FireWorks, shown in Figure 7. It was written and compiled with the ZeusPro compiler. This program will allow you to create script files that will turn lights and appliances on and off at various times. I have included the full ZeusPro source which includes documentation for the script editor. This is a work in progress, and eventually I want to create two-way versions for the other interfaces, as well.

SmartHome PowerLinc *(Model 1132B)*

The SmartHome 1132B shown in Figure 8 is a much more robust interface than the FireCracker. It offers full two-way X10 communications, as well as support for extended codes and data. You can purchase an 1132B for about $34 directly from SmartHome at **www.smarthome.com**.

The SmartHome 1132B has a more straightforward interface than that of the FireCracker. You communicate with the 1132B at 9600 baud, eight bits, and no parity using the standard RS-232 RX and TX leads.

1132B Reception

Using a free copy of ZeusLite, load up this program:

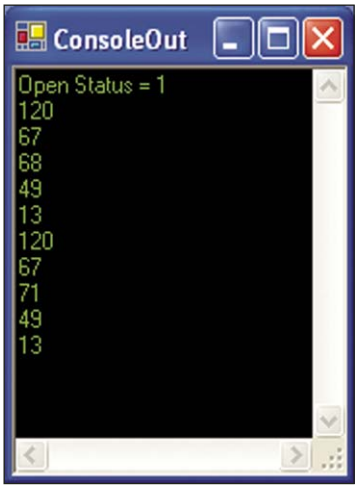
```
'[PLm1.txt] PowerLinc 1132B interface
func main()
  dim x as integer
  dim curchar as integer

  x=ComOpen(1,baud=9600,port=3) '<----- Set Port here
  print "Open Status = ";x
  ComBGSuspend(1,1)


loop2:
  curchar = ComGetByte(1)
  if curchar = -1 then goto loop2

  print curchar
  goto loop2

endfunc
```



■ FIGURE 9

1	0000 00000000
2	0000 00100000
3	0000 00010000
4	0000 00110000
5	0000 00001000
6	0000 00101000
7	0000 00011000
8	0000 00111000
9	0000 01000000
10	0000 01100000
11	0000 01010000
12	0000 01110000
13	0000 01001000
14	0000 01101000
15	0000 01011000
16	0000 01111000
9 On	0100 00000000
9 Off	0100 00100000
10 On	0100 00010000
10 Off	0100 00110000
11 On	0100 00001000
11 Off	0100 00101000
12 On	0100 00011000
12 Off	0100 00111000
13 On	0100 01000000
13 Off	0100 01100000
14 On	0100 01010000
14 Off	0100 01110000
15 On	0100 01001000
15 Off	0100 01101000
16 On	0100 01011000
16 Off	0100 01111000
Bright	0000 10001000
Dim	0000 10011000

■ TABLE 4

In this example, I issued the **K3-On** command using one of my X10 controllers. Each data packet reported on the 1132B begins with a 120 and ends with a 13, as shown in Figure 9. Excluding these bytes, the packet data actually consists of three bytes with the third always being 49. The first data byte is the house code and returns the values shown in Table 5. The second byte is the device/function code shown in Table 6.

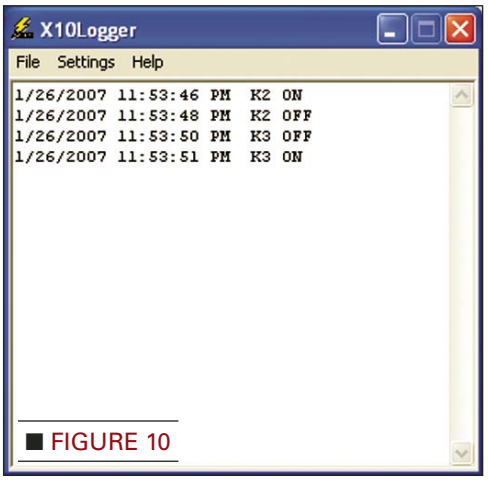
The 120 that starts the packet can also be replaced by other codes, such as 88 which represents the response to an 1132B transmission. The 49 value at the end of the packet also represents the number of transmissions detected. From what I have found, this is always 49.

Looking at Figure 10, two packets were received. The first data packet sets the target device; in this case, **K3**. The second packet sets the function **ON**.

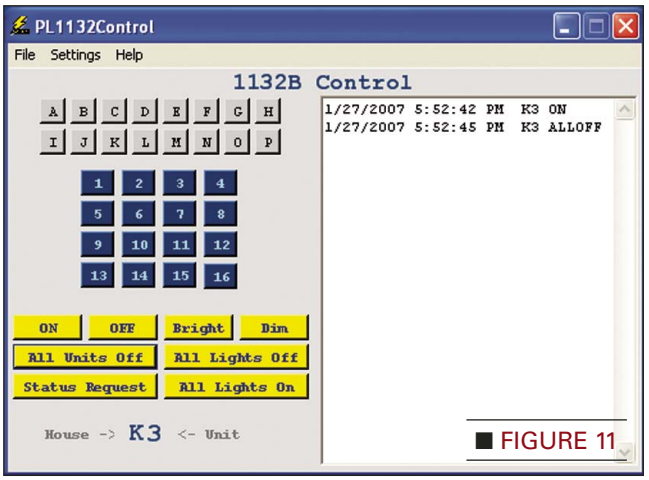
Load up the included program PLm3.txt. I have created

A	70
B	78
C	66
D	74
E	65
F	73
G	69
H	77
I	71
J	79
K	67
L	75
M	64
N	72
O	68
P	76

■ TABLE 5



■ FIGURE 10



■ FIGURE 11

a couple of routines to make 1132B reception fool-proof. The function called **check1132B** is called inside a loop and returns one of the following values:

0, No New Codes
1, New Device Set
2, Action Received

The following code snipit shows how you can access the three global variables HOUSE, DEVICE, and ACTION each time a status of 2 is received from the check1132B function:

```
loop2:
   stat = check1132B()

   if stat = 2 then
     print HOUSE,DEVICE,"Action="+ACTION
   endif

   goto loop2
```

As you can see, I have translated the raw data into usable values which could easily be translated into strings, if need be. I have included a ZeusPro program called X10Logger.exe in the download shown in Figure 10. This program will allow you to monitor the traffic on your power line for X10 activity.

	1	76
	2	92
	3	68
	4	84
	5	66
	6	82
	7	74
	8	90
	9	78
	10	94
	11	70
	12	86
	13	64
	14	80
	15	72
	16	88
Func 1	All Units Off	65
Func 2	All Lights On	67
Func 3	On	69
Func 4	Off	71
Func 5	Dim	73
Func 6	Bright	75
Func 7	All Lights Off	77
Func 8	Extended Code	79
Func 9	Hail Request	81
Func 10	Preset Dim High	87
Func 11	Preset Dim Low	85
Func 12	Extended Data	89
Func 13	Status On	91
Func 14	Status Off	93
Func 15	Status Request	95

■ TABLE 6

X10 Command	99
House Code	See Table 5
Unit Code	See Table 6
Function Code	See Table 6
Repeat Code	65

■ TABLE 7

■ FIGURE 12

1132B Transmission

Transmitting to a device is just a little bit more complicated. The first thing you need to do is to send the code 02 to start the transmission. The 1132B will respond with an ACK consisting of 06 and 13 if it is available, and 21 if it's not.

Once you receive the ACK, you are free to transmit your device code data. Table 7 shows the sequence of bytes that need to be transmitted. The Repeat Code shown is 65, which tells the 1132B that we want to transmit the code one time. The 1132B supports up to 15 transmissions of the code, which gives this field a range of 65-79. In most of the code examples, I have hard-coded this field to 65.

Once you send the data packet, the 1132B will respond with a data packet that we can capture and verify. The only difference is that the 120 start

packet code is replaced with an 88 to let us know it's a command response.

Take a look at program **PLm4.txt** included with the downloads. In this program, I added a function called **TX1132B()**. The command translates the house, unit, and function codes into the 1132B codes so that they can be transmitted. You simply pass the house code of 65-80 and the unit code 1-16 and the function you want to perform 1-16. The function codes start with the All Units On and proceed down the list as shown in Table 6.

After sending the code, the program calls the **check1132B()** function and displays the command results.

I have included yet another ZeusPro program called PL1132Control.exe shown in Figure 11. This program will let you control your X10 devices and will also log any activity.

RCA ActiveHome PC Interface *(Model HC60CRX or CM11A)*

The RCA HC60CRX shown in Figure 12 is actually the very popular CM11A. You can still find both online. The one I purchased I got for $19 including shipping from an eBay online store. Of the three interfaces I am presenting in this article, this is the most robust. It is also the most complicated.

Since the CM11A is much more complicated, I cannot detail every feature this little gem has to offer in the space of this article.

The interface is via a DB-9 cable and utilizes the standard RX and TX leads. The baud rate is 4800, eight-bits, and no parity. The RI pin is also provided that is brought high when data is available to be read.

CM11A Reception

Load up the following program into ZeusLite and run it. Make sure you set the port that is connected to the DB-9 connector on the CM11A.

```
func main()
   dim x as integer
   x=ComOpen(1,baud=4800,port=3) '<--- Set Port here
   print "Open Status = ";x
   ComBGSuspend(1,1)

   dim curchar as integer

loop2:
   curchar = ComGetByte(1)
   if curchar = -1 then
      goto loop2
   endif

   print curchar

   goto loop2

endfunc
```

As soon as you plug the CM11A into a power outlet, you will see the program start to print the code 165. This code is a request from the CM11A to set the internal timer. You won't be able to do anything else until you do.

In the program **CM11A2.txt**, I have added a function called **setCM11CurTime()**. This function sets the 56 bit fields of the internal clock on the CM11A. I use the PC's internal clock so there is no need to pass any variables. You could place a call to the function at the start of your program after you open the com port. However, I like to constantly look for the 165 code then make the call as needed. This way, any time the CM11A loses power the PC will reset the timer. The CM11A has two batteries that I had assumed would keep the timer running. This does not seem to be the case. If power is removed then restored, the CM11A will still respond with the 165 code.

You may have noticed that once the timer is set and you send an X10 code with one of your remotes, you see the code 90 start to appear. This is the CM11A's way of telling you that data is ready to be pulled from the interface. In **CM11A3.txt**, I added an additional **if** statement and when I see the code 90, I send back the code of 195 to tell the CM11A to transmit its information. The CM11A will transmit the 90 code once per second as long as data is in its buffer. In reality, you need to pull data from the CM11A much faster than once a second.

Table 8 shows that up to 10 bytes may be received at one time. The very first byte tells you how many bytes follow. The second byte is a mask that tells you which of the data bytes are address bytes and which are function bytes. If bit 0 in the mask byte is a 1, then Data 0 represents a function byte. If it's 0, then Data 0

Byte 0	Number of Bytes in Packet
Byte 1	Function/Address Mask
Byte 2	Data 0
Byte 3	Data 1
Byte 4	Data 2
Byte 5	Data 3
Byte 6	Data 4
Byte 7	Data 5
Byte 8	Data 6
Byte 9	Data 7

■ TABLE 8

BYTE 1							
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Dim Amount					1	Func	Ext
BYTE 2							
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
House Code				Unit/Function Code			

■ TABLE 9

is an address byte. Bit 1 maps to Data 1 and so on for all eight bits. There is one exception to this format: if a Dim or Bright function is received. The following byte represents the amount of the Dim or Bright. In my tests, this value always seemed to be 25.

If the data is an address byte, then the upper four bits are the house code and the lower four bits are the unit code. The house code maps directly to Table 1. The unit code maps to Table 2 minus the right-most bit, as shown. If the data is a function byte, the upper four bits map to the house code and the lower four bits map to the function code (Tables 1 and 2).

In program **CM11A4.txt**, I added a function called **checkCM11A()**. This function collects the data transmitted by the CM11A and then processes the packet once all the bytes in a single packet have been received. The function is called once every 10 ms and if the 90 code is not found, it sends the data request code of 165 regardless. This ensures that I can keep the CM11A buffer clear and process the commands in a timely manner.

CM11A Transmission

In order to transmit an X10 code, you need to send two bytes. The first byte is the header byte and uses the format shown in Table 9.

The upper five bits are only used when doing a Dim or Bright function. It is supposed to direct how many times the CM11A transmits the command. In all the tests I have performed, it looks like only bits 5-7 are used and will transmit from one to seven times. In all my examples, I leave all the Dim bits at 0. This will cause the Dim or Bright function to be issued once for each call. Bit 2 in the header is always 1. Bit 1 is set to 1 to flag a function (House/Function) code for the second byte in the transmission. If it's set to 0, the second byte is an address (House/Unit). Bit 0 is used to flag an extended format which I am not covering in this article, so it's set to 0.

After transmitting these two bytes, you will receive an eight-bit checksum and the CM11A expects you to send a 0 to indicate the checksum is a valid one. The CM11A will then respond with an 85, a code which indicates that it is ready once again.

In program **CM11A5.txt**, I added a function called **TXCM11A()**. Just like the TX1132B() function we created for the 1132B, you pass the house code 65-80, device code 1-16, and action code 1-16. The **TXCM11A()** function sends two command sequences to the CM11A. The first is an address sequence and the second is a function sequence.

One of the deficiencies of the CM11A interface is that if any data is in the interface buffer, the transmission of an X10 code will fail. At the very start of the **TXCM11A()** function, I make a call to the **CollectCM11Adata()** function. This will empty the buffer and allow us to proceed with the transmission.

I have created two extra ZeusPro programs called CM11Logger.exe and CM11AControl.ext, shown in Figure 1. Just like the 1132B, you can use them as a controller or logger for your X10 network.

X10 Performance Tips

A few notes on X10 performance. Do not place X10 devices or interfaces on power strips. Many have suppression capacitors that will affect the performance of both. In some cases, they may not work at all. The same goes for battery-powered UPS systems. If you start to have problems with your X10 device or interface, move it to a different location and try again. I don't recommend X10 systems for critical systems as it can be unreliable under certain circumstances. They do sell two-way appliance and lamp modules to allow you to poll their status in order to verify they have the correct settings you have sent them.

Final Thoughts

All three of the interfaces presented here have their place. But for real automation, you should look into the 1132B or the CM11A. It's a simple matter to take a very inexpensive X10 motion detector and automatically control lights or other devices upon entry into or exit from a room.

In many cases, we can't devote a PC to our home automation system or weather station, so starting next month, I am going to begin the process of migrating these projects to one or more microcontrollers. The microcontroller interface will also yield other advantages such as faster A-to-D conversion and the ability to interface to more sensor types.

NOTE: All the example programs, as well as the source code, are available for download at **www.kronosrobotics.com/Projects/x10.shtml**. **NV**

Links

■ *Kronos Robotics*
www.kronosrobotics.com/xcart/customer/home.php

■ *KRMicros*
www.krmicros.com/Development/ZeusPro/ZeusPro.htm

www.krmicros.com/Development/ZeusLite/ZeusLite.htm

■ *SmartHome*
www.smarthome.com/1132b.html

■ *X10*
www.x10.com

BY GERARD FONTE

PULSE SPEED TIMER

There is a delay between when your heart beats and when the pulse is felt at your wrist (or elsewhere).

This delay depends upon a number of physical factors, including the elasticity of the walls of the arteries. This project will allow you to measure this delay and will also provide a platform for acquiring some practical experience with high-gain analog and mixed-signal design. The output of the project is a digital pulse with a duration equal to the difference between the start of the heartbeat and the pulse.

The human circulatory system is not simply a lot of plumbing. There are a number of subtle factors that nature has provided to aid in the ability of the heart to push blood around the body. One of the most important is the elasticity of the walls of the arteries. This elasticity is easily observed by simply feeling one's own pulse at the wrist. The small artery there can be felt expanding and contracting with every beat of the heart. If there were no expansion and contraction, the pulse would be much harder to feel.

This action sets up something like a peristaltic wave that helps to push the blood through the circulatory system. In short, the elasticity of the arteries is important for good blood flow. It's well known that "hardening of the arteries" from cholesterol build-up is not good.

There are two general types of waves found in nature: transverse and compression. A transverse wave changes the amplitude of the medium. Ripples on the surface of a pond are transverse waves. Compression waves change the density of the medium. The most common compression wave is sound. Sound changes the density of the air, not its height.

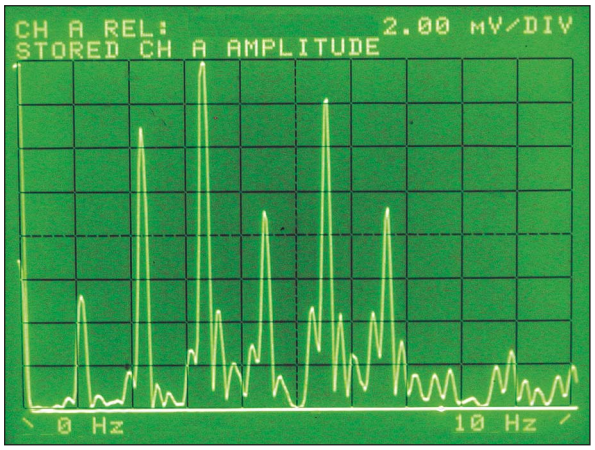
Speculation

The elasticity of the arterial walls means that the pulse wave acts somewhat like a transverse wave. One characteristic of a transverse wave in a liquid is that it's fairly slow. Ripples on a pond move relatively slowly. They rely on the external restoring-force of gravity to propagate.

However, the propagation of a compression wave in a liquid can be extremely fast. Here, the speed of propagation depends on the compressibility of the liquid and the walls containing it. For example, consider water in a filled copper pipe. There is very little delay from the time more water is forced into one end to the time water comes out of the other end. In this case, system pressure is an important factor.

Therefore, it was thought that the propagation speed of the human pulse should increase if the elasticity of the arterial walls decreases because the pulse wave is changing from a transverse wave to a compression wave. Initially, no references could be found. However, recently a paper by doctors Safer, Henry, and Meaume (2002) was found (see reference at end) that indicated that the speed of the pulse does indeed increase with lower arterial elasticity.

A somewhat more subtle factor should also be observed. This is the change in wave shape. There is every reason to believe that there will be a different wave shape when comparing a compression wave to a transverse wave. This should be especially true for the same system when the elasticity of the retaining walls has changed. It would be expected that higher frequency components would appear as the pulse wave propagation speed increases. No references concerning that factor could be found (but that doesn't



■ PHOTO 1. Here is the FFT of the pulse taken at the wrist. Note that this is a linear scale. It is also noteworthy that no signals above 10 Hz were seen.

mean there aren't any).

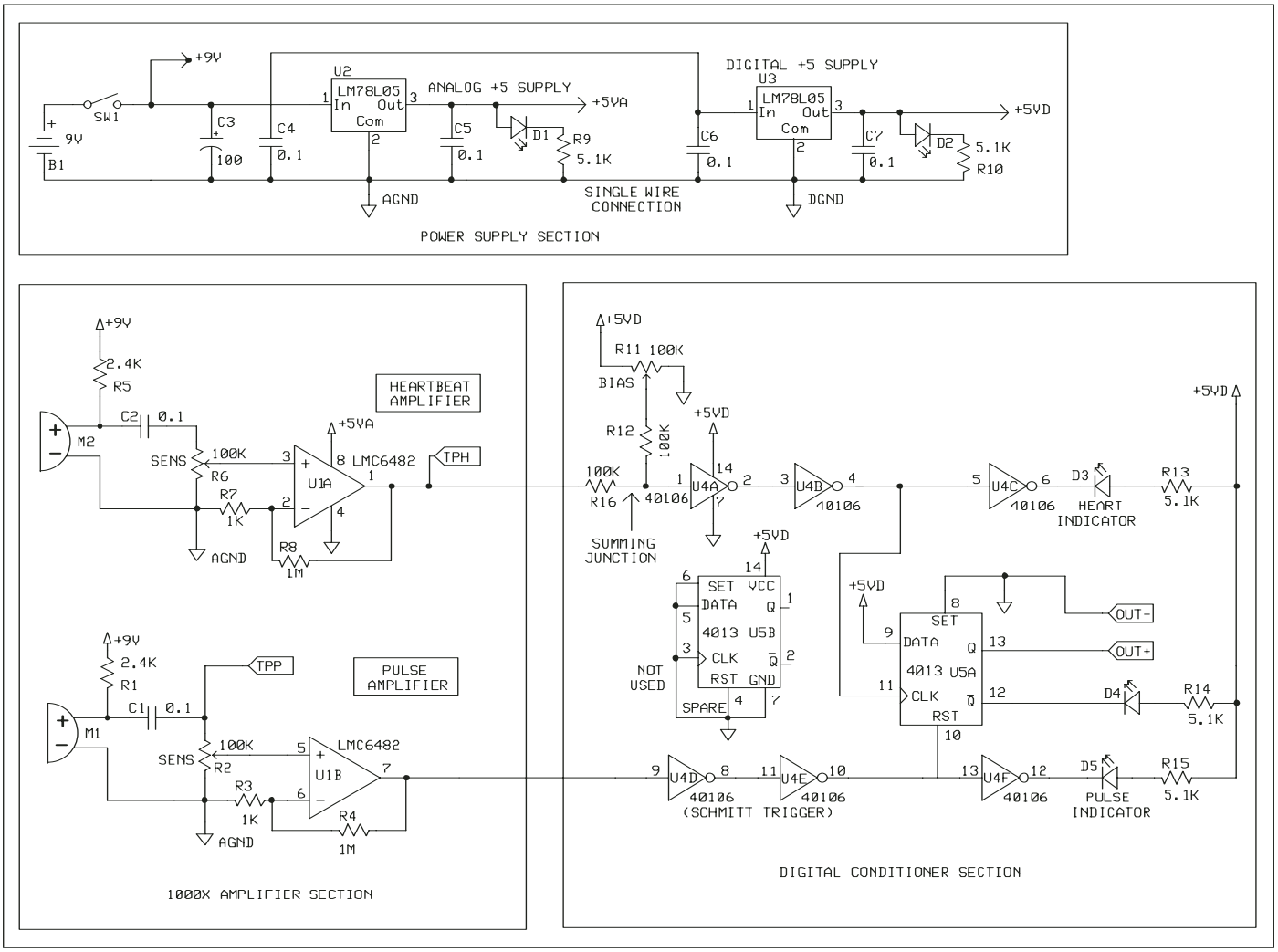
Going further, it would not be surprising to find that a normal human pulse wave would have a soliton wave shape. After all, nature has had a long time working out the kinks in circulatory systems and a soliton wave is very efficient. (Soliton waves are self-reinforcing waves that propagate without distortion based on non-linear characteristics of the medium.) Photo 1 shows an FFT of my (mostly) normal wrist pulse. It is unknown if this matches a soliton wave. (If you know, please tell me.)

The Power Supply

Figure 1 is the schematic diagram of the pulse speed timer. There are two important things to note right away. The first is that this is a mixed-signal design. Both analog and digital components are used. The second is that the analog section has amplifiers with gains of 1,000. Putting all this together will require some special attention.

The power supply section is pretty much basic, except that there are a few subtle points that need to be discussed. When working with high-gain and/or mixed signal designs, power-supply (PS) noise can be a real problem. PS noise shows itself in two different ways. Obviously, it doesn't take much noise to drown out your signal. This is especially true with low-level signals requiring high-gain amplifiers.

■ FIGURE 1. The schematic diagram of the project consists of three sections: power supply, amplifier, and conditioner. This is a high-gain, mixed-signal design that requires proper techniques to function accurately.



The second point is that PS noise can cause oscillation. When digital signals switch, they can cause the power supply voltage to drop. This can change the internal bias of the amplifiers which may cause them to draw more power and/or shift the output voltage.

Since op-amps use negative feedback, any change in the output will be "corrected" by the amplifier, which causes an output shift and can cause additional power supply variations. Unfortunately, the op-amp cannot respond instantaneously, so this correction is delayed to some degree. At some point, if the correction if large enough and of the proper polarity, positive feedback will occur which can cause ringing or full-blown oscillation. To reduce PS noise, three isolated voltages are used.

The +9 volts are used for the electret microphones. This is done for two reasons. The first is to isolate them from any other power supply. Since their output is directly related to the positive supply, any noise here will be directly coupled into the output. Note that this +9 volts is well bypassed and isolated from the other two supplies. The second reason is that the +9 volt supply will provide a larger signal than using a +5 volt supply.

There are two +5 volt supplies: one for the analog circuit and the other for the digital circuit. Again, this is to reduce noise coupling. A very important point is that there is one and only one connection between the analog ground (AGND) and the digital ground (DGND). More than one ground interconnection can cause ground loops between the analog and digital circuits. Ground loops couple noise and allow differential currents to flow. Not good. The single ground connection should be at the power supplies.

I used low-power, three-terminal regulators. You can use the high-power version if it's more convenient. I also added LEDs as a visual indicator that the power supplies were working. I find this useful, but it's not necessary. Since I had high-intensity LEDs on hand, I used 5.1K current limiting resistors for R9 and R10. If you have less bright LEDs, you may want to change the resistors to 1K or even 510 ohms.

The Amplifier

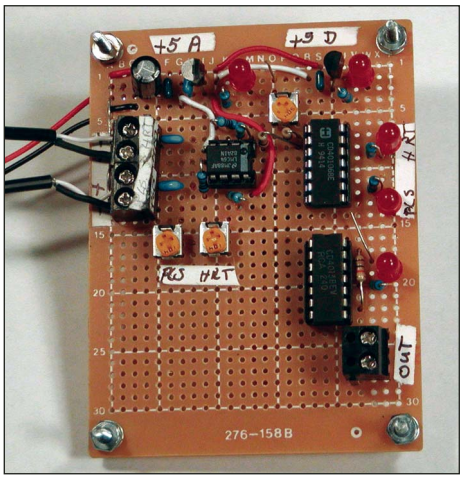
I chose the LMC6482 op-amp because I had it on hand, as well. The CMRR (Common Mode Rejection Ratio) and PSRR (Power Supply Rejection Ratio) are good for the LMC6482 (at 82 dB). Most single supply amplifiers should work reasonably well. If you have noise problems with your amp, these are the characteristics to compare. The input impedance of your amplifier should be in the megohms, at least (the LMC6482 has >10 teraohm input impedance).

Both amplifiers are the same. Keep the leads short and close to the amplifier. If you stand the gain resistors — R7 and R8, R4, and R5 — on end like I did (see Photo 2), place the body of the resistor at the input pin of the op-amp. This eliminates the small amount of noise that might come in from the 1/2 inch of exposed resistor lead. (Every little bit helps!) Ordinary point-to-point wiring was used, but care was taken to keep the lead dress as short as possible.

The variable resistors (R2, R6) are used to set the sensitivity of the amplifiers. The full gain of 1,000 may not be needed. The input capacitor (C1, C2) is used to block the DC that is present at the electret microphone. The microphone resistor (R1, R5) is used to supply power and limit the current to the microphone.

Microphone Construction

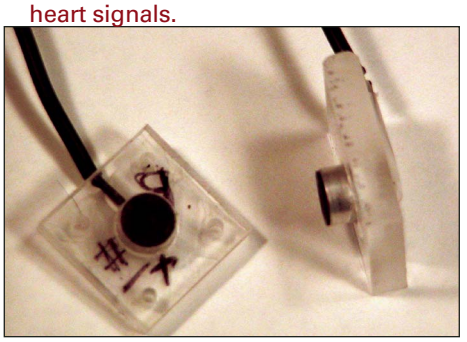
A number of different microphones were tried with various levels of success. The best all-around performance came from an ordinary electret microphone. I used ones I already had, which are apparently now obsolete. They are about 0.27″ high and 0.39″ in diameter. This appears to be similar to Jameco 320178CK, but anything with good low frequency response (about 20 Hz) should work fine. I attached the microphones to a one inch square piece of 0.25″ thick plexiglas (see Photo 3). I drilled a hole slightly larger than the diameter of the microphone, *almost* all the way through the plastic so that the microphone would have a solid backing. I drilled a smaller hole the rest of the way through for the wires.

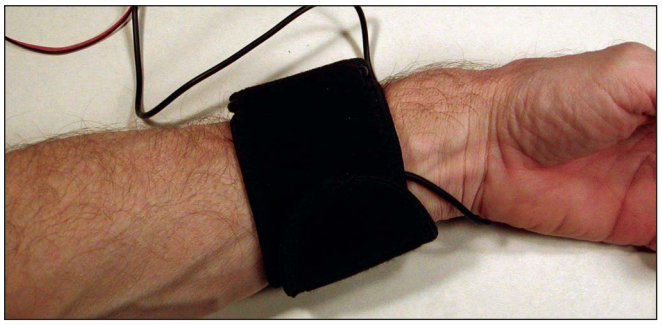


■ PHOTO 2. The circuit board layout is straightforward. Point-to-point wiring was used but care was taken to keep leads short and to separate the analog section from the digital section.

The microphone was set in place with silicone adhesive. Note that about 0.2″ of the microphone protrudes from the face of the plastic. This projection is important because it presses the microphone into the skin. You must use shielded cable for the wires and keep the length to a maximum of 24″. Also be sure to observe the polarity of the microphone leads. The center conductor of the shielded cable goes to the positive terminal.

■ PHOTO 3. The microphones were cemented into plexiglas holders about an inch square with silicone adhesive. The protrusion of the microphones provides better pick-up of pulse and heart signals.





■ PHOTO 4. The microphones are held in place with elastic straps and velcro. Placing the microphone at the forearm provided a better signal than at the wrist. This is a commercial wrist-strap. The chest-strap was homemade.

The Digital Signal Conditioner

The heart of the conditioner is the 4013 D Flip-Flop that is configured as a Set/Reset Flip-Flop. The heartbeat clocks a "1" into the 4013, setting it. This state remains until the pulse signal resets it. Therefore, the output pulse length is equal to the difference in time between the heartbeat and pulse. Unfortunately, things aren't quite as simple as that.

The input signals from the analog circuit have to be converted to proper digital signals. This is done with the 40106 Hex Schmitt-trigger chip. This device uses hysteresis to create clean, sharp digital signals from slow-rising analog signals. Since the triggers act as inverters, two sections are used for each signal to maintain the proper polarity.

The extra sections are used to drive LEDs. Note that it is possible to connect the LEDs after the first section, but that would load the signal, possibly causing problems. Since two spare sections are available, it makes sense to use them to eliminate any possibility of loading problems. The 4000 series chips sink much more current than they can source, therefore the LEDs are connected as shown. The maximum sink current for the 4000 series is about 4 mA. So you can use smaller resistor values and less bright LEDs, if desired. This applies to the 4013 pulse output LED, as well.

There is a special circuit that consists of R16, R11, and R12. It turns out that the heartbeat signal is still too small (about 1+ volts) to directly trigger a digital circuit. To fix this problem, a bias voltage is generated and added to the input voltage. So, instead of a 0 to 1.3 volt signal, a DC bias of about 1.5 volts is added to create a signal of 1.5 to 2.8 volts. This new signal will trigger the 40106 input properly. R11 provides the bias voltage that is summed with the heartbeat signal via R12 and R16.

The 4000 series of chips was chosen specifically because they are slow and require very little power. There is no need for speed in this application. And the slower the transitions, the less PS noise and less EMI (electromagnetic interference) is generated. Additionally, the low power means there will be less drain on the power supply, which also lessens any PS noise. The 4000 series parts may be old and slow, but they are very useful in applications like this.

PARTS LIST

CAPACITORS (all 25 volts or greater)

❑ C1-C3, C5-C7	0.1 µF
❑ C4	10 µF

RESISTORS (1/4 watt fixed, 5% except as noted)

❑ R1, R5	2.4K
❑ R3, R7	1K
❑ R2, R6, R11	100K Potentiometer
❑ R4, R8	1M
❑ R9, R10, R13-R15	5.1K
❑ R12, R16	100K

SEMICONDUCTORS

❑ D1-D5	Red LED
❑ U1	LMC6482 Op-amp
❑ U2, U3	LM78L05; Low Power +5 Volt Regulator
❑ U4	CD40106; Hex Schmitt-Trigger
❑ U5	CD4013; Dual D Flip-Flop

MISCELLANEOUS

❑ SW1	SPST Switch
❑ M1, M2	Electret Microphone (see text)
❑ B1	Nine-volt Battery

Operation

In theory, the operation is very simple. Attach the pulse microphone to the wrist to obtain the wrist pulse and attach the heartbeat microphone to the chest and measure the output pulse length on any oscilloscope or with an interval timer, or just look at the output LED for a qualitative indication. However, it's a bit tricker than that in practice.

The microphones must be attached — rather than held — in place because the microphones are very sensitive to any movement. Holding them in place creates way too much movement noise. Elastic bands and Velcro works well. The pulse microphone works best if placed on the forearm rather than the wrist — for me anyway (see Photo 4). In fact, an extremely good signal of greater than 100 mV was obtained from the microphone directly (measured at TPP). Few problems occurred here.

The heartbeat microphone was attached in a similar manner. However, the signal was much weaker; only a millivolt or two. Different placements yield different signals and strengths. Posture can affect the signal. Additionally, the heartbeat consists of two distinct signals: "Lub-Dub." Sometimes the second signal was the largest. This occurred well after

the pulse had propagated to the other microphone. Naturally, that causes problems when the circuit triggers on that.

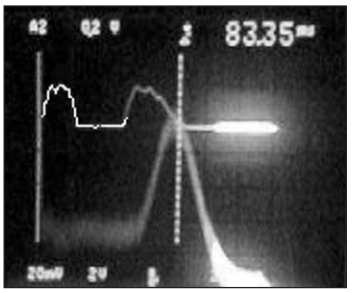
There is also the issue of triggering on the same point of each signal. Since the signals are over 100 ms in length and the delay to be measured is less than that, the trigger points must be right at the beginning of the signal. This works well for the pulse signal, which is very large. However, it is more problematic with the heartbeat signal, which is much smaller. There is a much greater likelihood that the heartbeat signal will be delayed until the signal reaches a sufficient level to trigger the circuit.

It is certainly possible to measure the signals directly with an oscilloscope without using the signal conditioner section. This is shown in Photo 5. (Note: The figure is retouched to show the beginning of the heartbeat trace. It was difficult to get a good picture of a single-shot event with a nonsynchronized camera. The zero-voltage, flat part of the heartbeat trace is presumed to be a negative signal that was clipped because the op-amp is using a single supply and can't handle negative input voltages.) The proper delay is from the start of the heartbeat and the start of the pulse. The second time-bar in not placed properly. The proper delay is approximately 60 ms (not 83 ms).

This procedure can provide a fairly accurate measure of the delay. In this case, the delay is about 60 ms from heartbeat to wrist. The straight-line distance is 27 inches. This corresponds to about 2.2 mS per inch or 27 mS per foot. Converting to speed: 454 inches per second or 37 feet per second.

Going Farther

In order to reduce the variability of the digital conditioning circuit, the pulse and heartbeat signals need to be the same size and triggered at the same point. One way to improve matters significantly is to couple the microphone to an inexpensive stethoscope. This was tested and a very nice signal of over 100 mV before the amplifier was obtained. This is very similar to the pulse voltage.



■ PHOTO 5. Actual delay measurement taken at TPP and TPH (see Figure 1). Actual delay is about 60 ms (not 83 as shown). The beginning of the heartbeat signal was retouched for clarity. (It's very difficult to synchronize a camera to an oscilloscope!)

These signals should be passed through an AGC (automatic gain control) to get them to match well. Then a comparator could be used to create the digital signal. (This would make the project too complex for most readers, however.) The polarity of the signals should also be the same. The pulse moves the skin outward to start. Depending on where you place the sensor, the heartbeat may or may not do the same.

It should also be noted that the reference article refers to aortic pulse velocity, not peripheral pulse velocity. So it is not proper to directly compare the numbers presented there with the delays measured here. (Additionally, some of the statistics appear suspect.) And always remember to leave the medical diagnoses to the professionals.

Conclusion

It is possible to measure the propagation speed of the blood pulse from the heart to the forearm with a simple circuit. In the process of building this, practical experience in high-gain amplifiers and mixed-signal designs can be obtained. **NV**

Reference

Aortic Pulse Wave Velocity: An Independent Marker of Cardiovascular Risk, Michel Safer MD, Oliver Henry MD, Sylvie Meaume MD, 2002 Medscape. **www.medscape.com/viewartile/443202**

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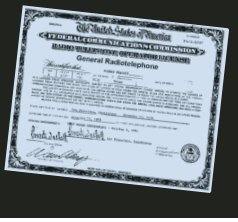

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The SchmartAdvocate program is designed to spread the word about SchmartBoard prototyping boards among electronics and robotics clubs, universities, and other enthusiasts. SchmartAdvocates will receive commissions, bonuses, and other perks in return for talking about SchmartBoards from experience as a user and passing out materials. A 20% commission will be paid on orders that come from the work of SchmartAdvocates.

SchmartBoard|ez prototyping boards allow virtually anyone to hand-solder surface-mount components easily, quickly, and flawlessly. Prior to the development of this technology in late 2005, few people had the dexterity to hand-solder surface-mount components with pitches as tiny as 0.4 mm.

"People cannot believe how easy it is to hand-solder surface-mount components with our product unless they try it for themselves. It is for this reason that we need to get demo boards in the hands of the right people," said Neal Greenberg, SchmartBoard's vice president of sales and marketing. "We are looking for influential people involved in industry, education, and clubs to simply hand out samples to friends and colleagues."

The people who try SchmartBoard due to their SchmartAdvocates will also receive bonuses if they make a SchmartBoard purchase. Those interested in this limited opportunity can fill out an application at: **www.schmartboard.com/index.asp?page=schmartland_advocate.** The program is currently limited to the US, but may expand at a later date.

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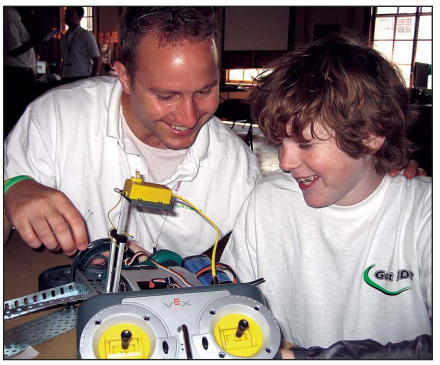
HANDS-ON LEARNING HELPS KIDS EXPRESS THEMSELVES



Project-based learning at iD Tech Camps — a family-owned Silicon Valley-based company now in its ninth season — gives kids just the kind of hands-on learning experience that will make a difference in their lives. iD Tech Camps produces and runs weeklong day and overnight summer technology

programs for Digital Kids ages seven to 17 at 50 prestigious universities in 23 states (**www.internaldrive.com**).

Locations include Columbia University, Stanford University, Georgetown University, Brown University, UCLA, and Northwestern University.

Project-based learning shifts away from traditional classroom lectures. Instead, it actively engages students by promoting understanding, empowering kids, and motivating them with energetic, lifelong investigative learning.

According to the George Lucas Educational Foundation, with project-based learning in the classroom, there is a decline in absenteeism, an increase in cooperative learning skills, and improvement in student achievement. These benefits are heightened even further when technology is integrated into projects.

With this hands-on approach, learning becomes more relevant to kids and helps them to establish connections to the "real world." When students are more attentive, they retain more knowledge. This knowledge can then be applied to students' current and future schoolwork, hobbies, and eventually a career.

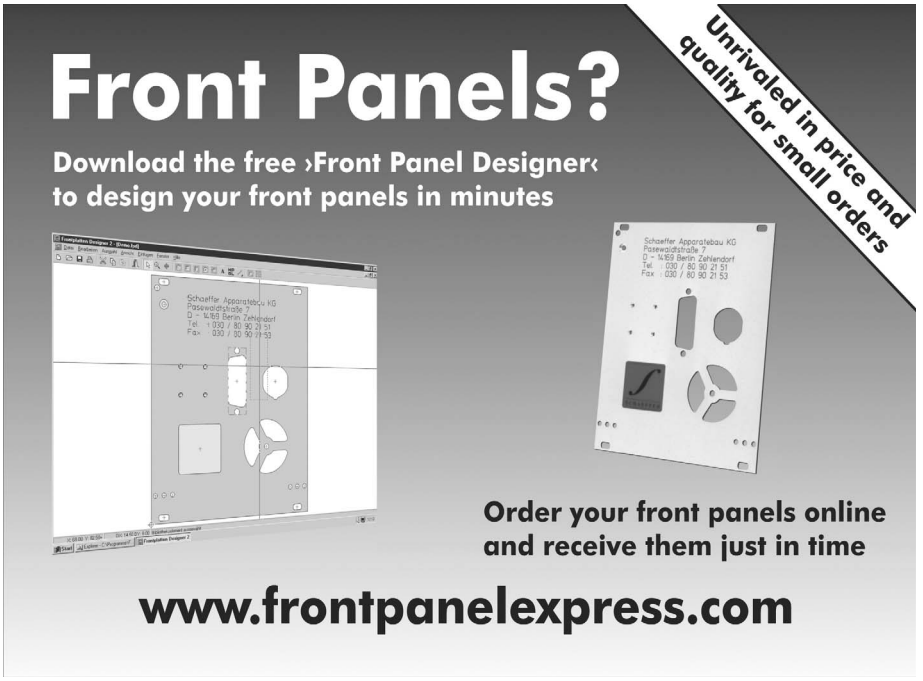
Each student has a different style of learning. What once was difficult to articulate in a written report can now be demonstrated powerfully through digital movies and other multimedia vehicles. Learning through hands-on projects allows students to delve into the content in a more direct and meaningful way.

Project-based learning is the core of the iD Tech Camps philosophy. "Our teaching philosophy is 'experience-based' which means from the moment the students enter our lab, the experience is hands-on," said Karen Thurm Safran, VP of Marketing. "We challenge and guide our students, encouraging each to experiment. Students work at their own pace and prepare for the grand debut of their projects at the end of the week using industry-standard products like Adobe® Photoshop®, Autodesk® 3ds max, and Apple® Final Cut Pro®."

During the last 10 years, the Secretary of Labor selected a commission to determine necessary 21st-Century Digital Age skills for competing in the working world. What may have worked in the past — simply focusing on the "3Rs" of reading, writing and arithmetic — doesn't hold up for today's kids. Instead, the following Digital Age skills have been identified: teamwork, planning, problem solving, critical thinking, researching, information synthesizing, using technology, and communicating.

A number of those Digital Age skills are developed through project-based learning, including knowing how to work well with others, making careful decisions, being proactive, and solving difficult problems. Thanks to hands-on learning, students are paving the way to future careers filled with independence, critical thinking, and lifelong learning.

Continued on page 61



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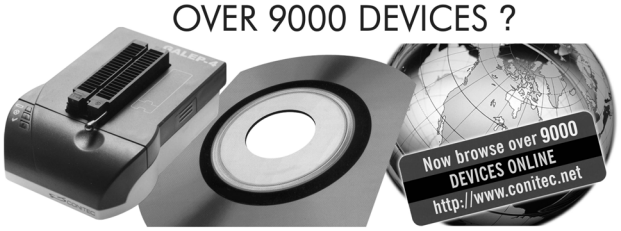

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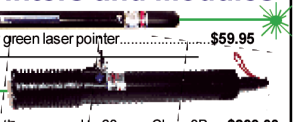

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Green - Class IIIa 3 volt modules
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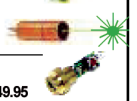

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28K074 - 4kv 15ma 30 khz 9-14v 1"cube....**$17.95**
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CD45 - 40 kv trigger pulse 1.25 x 1.25.....**$18.95**
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FLYLABURN - 10 kv 60 ma end grd.....**$49.95**
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FLYPVM400HP - High power flyback.....**$34.95**

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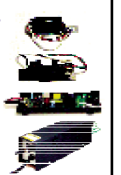

MINIMAX2 - 2kv 10 ma 50 khz **$17.95**
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Continued from Page 6

Mechanical generators will produce true sine wave power. Most electronic power inverters produce modified sine wave power that approximates a sine wave. There are more expensive electronic inverters that will produce "true" sine wave power. Consider that grid-tie inverters are capable of back-feeding the grid in order to sell electricity back to the power company – this requires very close tolerances in both sine wave quality, as well as isochronous phase timing.

An inverter running off a car is not as strange as it sounds. Many utilities run power from their trucks using large electronic inverters, including power companies. This allows them to have power when the grid is unavailable, and it is electrically isolated from the grid. Many RVs and motorhomes are running generators and inverters as power options.

Most generators have a bonded ground, meaning the neutral wire is connected to the chassis and ground. Once it is connected to your service panel (via a grounded cable), its neutral is locally grounded. Not connecting neutral and ground correctly is a potential safety issue; not a guarantee of death and destruction, but it could be. Proper electrical wiring and use is a good habit to follow. I cannot safely advise you otherwise, but if you are in doubt about the operation of your setup, again, consult your manufacturer(s), or a power consultant. If you have any doubts about your ability to work with home power, it is best to enlist the services of a qualified and licensed electrical contractor to do the necessary work. Also, I am not recommending you leave an inverter permanently connected to your furnace, only as a temporary measure until either power is restored, or until you can get an alternate power source in place.

Kenton Chun

PINOUTS YES, iPOD NO

I really like your magazine. Every issue has something useful. Your last issue had an article about iPod interfacing, which does not interest me, but the pinouts for USB and the schematics for the electret preamp and RS-232 interface were great.

David Murphy

PREFERENCE FOR PICAXE

Ron Hackett made a compelling case for the PICAXE in his recent article series. It comes down to an extremely low cost, and fast development and prototyping. Unlike most Stamp-like devices, this one can be purchased at very low prices, making it affordable for the very small automation circuits that don't justify a $50 MCU controller. Also, the fact that we don't have to buy a separate compiler or hardware programming device makes the PICAXE a "no brainer" purchase! By the way, there's a small typo in the link for the maker of the PICAXE – you need a hyphen: **www.rev-ed.co.uk**.

Eric Engler

Continued on Page 92

THE MYSTERIOUS MAGIC BOX

Part 1

This unique DIY construction project blends electronics technology with carefully planned handcraftsmanship.

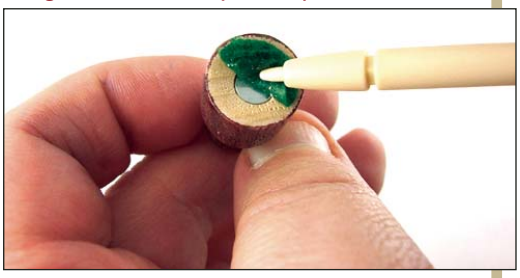
It is where the old world meets the new.

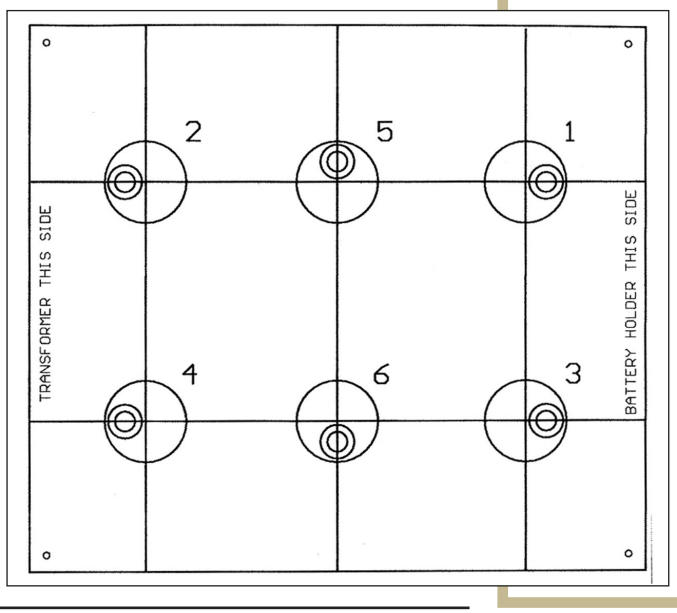
Its delightful innovative twists will surely amuse you. More importantly, though, it bewilders, baffles, and mystifies those observing this subtle, magic trick.

Imagine two rows of pawns residing inside an ancient, well-worn wooden box with rustic hardware. Ask an observer to remove a pawn or two, then close and latch the lid after you leave the room. You re-enter the room and astound onlookers by miraculously identifying the positions of the removed pawns — without ever opening the box!

Magicians and magic books both stress the importance of a good trick's simplicity, while still puzzling its observers — and this electronic project does both!

■ FIGURE 1. A pawn with an embedded magnet, covered by a felt pad.





■ FIGURE 2. The alignment pattern showing the pawn numbering sequence.

Exploiting Magnetism's "Invisibility"

You embed each pawn's base with a 1/4-inch diameter "neo" (neodymium) magnet and conceal it with a felt pad (Figure 1). Each pawn's corresponding Hall Effect sensor (hidden underneath it) detects a magnetic field and generates a logic level to a missing pulse detector. This drives a transformer whose output causes a tingling sensation when you touch the box's rear hinges, to which it is wired.

Detection occurs from a long pulse followed by six shorter pulses (one for each pawn). When you remove a pawn, you'll miss one of the shorter pulses in the sequence. This corresponds to that particular missing pawn. With practice, you can even detect two missing pawns.

For those interested, a complete kit of parts is available for purchase. References to this kit will be made throughout the article. However, you should be able to construct the project on your own if you prefer, with the information presented.

Figure 2 shows the layout pattern (not to scale) of each pawn's position and its order in the numbering sequence.

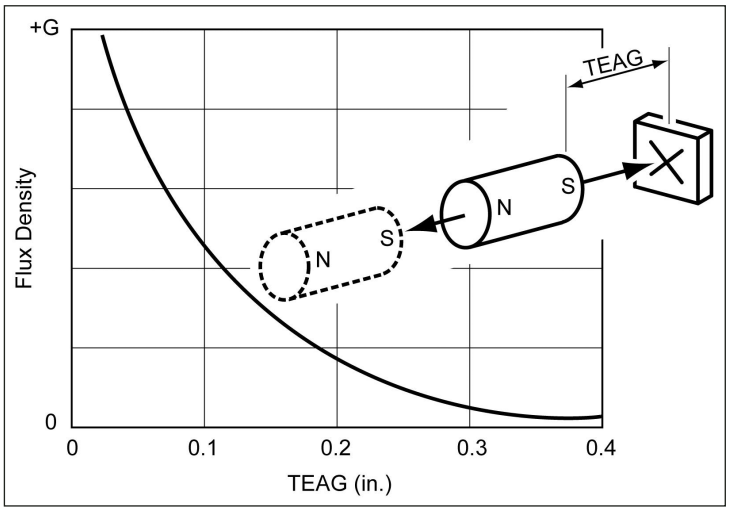
Rare Earth Magnets

Neodymium or rare Earth

magnets are very powerful compared to their own weight. Three substances comprise this magnet: neodymium, iron, and boron — $Nd_2Fe_{14}B$. They are now so economical they have replaced the more heat-resistant samarium-cobalt magnets. Samarian-cobalt's Curie temperature is about 800°C compared to 310°C for rare earth magnets. Exceeding Curie temperatures in ferromagnetic materials nullifies their magnetic ability.

The toy industry uses millions of these in magnetic products such as building sets and jewelry. Apple's popular iPod music player uses them for the transducers in the earphones. A downside to these magnets is their mechanical brittleness. The edges are highly susceptible to chipping. Fortunately, this does not affect their ability to function properly, whatsoever. Another downside is that these magnets are powerful enough to irreparably damage the contents of a floppy disc and erase data on magnetic stripes of credit cards.

Neodymium magnets can also magnetize color CRT shadow masks, and physically deform them so severely that even going through a degaussing repair process is useless.



■ FIGURE 3. The magnet's travel path related to field strength. Artwork courtesy of Allegro Microsystems.

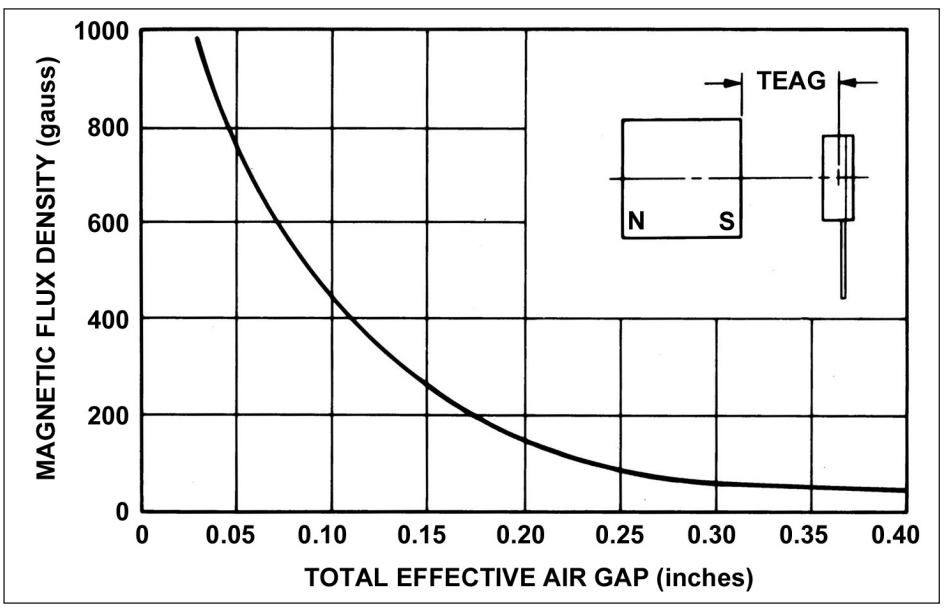
Grading and Field Strength

Neodymium magnet strengths are graded over a range of N24 to the strongest of N54. The N number represents the magnetic energy product, in MegaGauss-Oersteds (MGOe) (1 MG·Oe = 7,957 T·kA/m = 7,957 kJ/m^3). Magnets included in the kit are mid-range in strength.

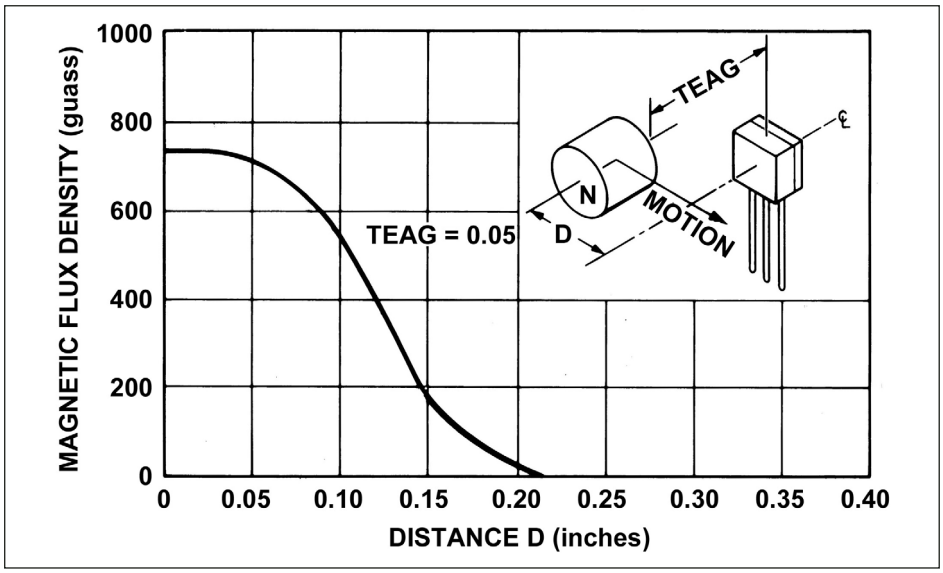
A magnet's field strength is greatest at the pole face, and naturally decreases with increasing distance from the magnet (also referred to as Total Effective Air Gap or TEAG). You can measure the strength of the magnetic field with a Gaussmeter or a calibrated linear Hall Effect sensor. If you plot field strength (magnetic flux density), you will discover it is a function of distance along the intended line of travel of the magnet (see Figure 3).

The site **www.coolmagnetman.com/magmeter.htm** shows how to use another Allegro Hall Effect sensor to make your own Gaussmeter. If this intrigues you, reference Allegro's web page at **www.allegromicro.com/demo/3515-6.htm** and you will find a calibrated Hall Effect sensor that you can buy online for about $25. This is an accurate, easy-to-use tool for measuring magnetic flux densities. The manufacturer individually calibrates these devices over their linear magnetic span and furnishes you with a reference curve and specific sensitivity and quiescent outputs at 4.5V, 5.0V, and 5.5V.

You specify sensitivity in mV/G for a linear device, or operate and release points in Gauss for a digital device. This allows you to determine the critical distances (TEAG) for a particular magnet and type of motion (see Figure 4). Field strength plots are not linear, especially when you place the magnet off-axis from the Hall Effect sensor's centerline (see Figure 5). I used an acrylic sheet 80/1,000's of an inch thick to

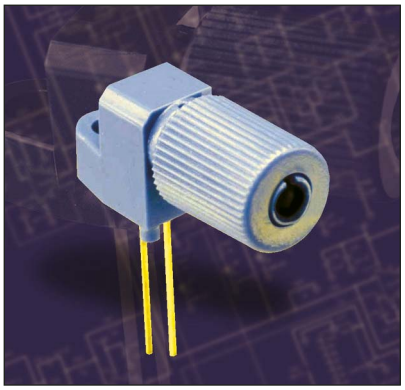


■ FIGURE 4. The magnet's critical separation distance. Artwork courtesy of Allegro Microsystems.



■ FIGURE 5. A nonlinear magnetic field strength plot for placement of the magnet 0.05" off the Hall-Effect sensor's centerline. Artwork courtesy of Allegro Microsystems.

■ FIGURE 6. The six pawn enhanced and the four pawn standard versions of the kit.



■ FIGURE 7. The IF-E96 LED optical fiber holding module. Artwork courtesy of Industrial Fiber Optics, Inc.

separate the magnets and Hall Effect sensors. Be sure to abut the sensors absolutely flush with the acrylic, however.

The shape of the flux density curve greatly depends upon the magnet's shape, the magnetic circuit, and the magnet's travel path.

Pick Your Pawns

This project comes in two versions (Figure 6). The standard four pawn version uses the tactile missing pawn detection method described previously. The enhanced six pawn version uses the same tactile method, but includes a visual indicator as well (see Figure 7). **SPECIAL NOTE: Because of the tingling sensation which occurs, if you have a heart murmur, pacemaker, or suffer from epileptic seizures, it's highly recommended to go with the visual indicator version only.**

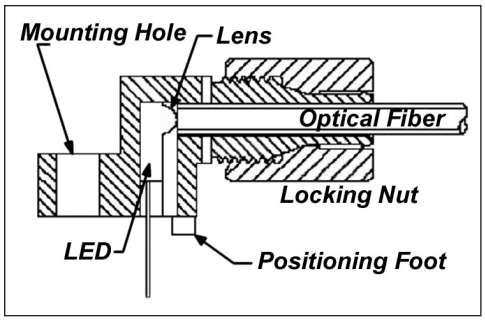
The visual indicator has an encapsulating shroud over an LED and a micro-lens with which to efficiently direct and couple its optical energy down an optical fiber. The 660 nm (medium red) LED and its optical fiber (matched to within 10 nm) result in a minimal index of diffraction mismatch losses.

The Fiber Optic LED Module

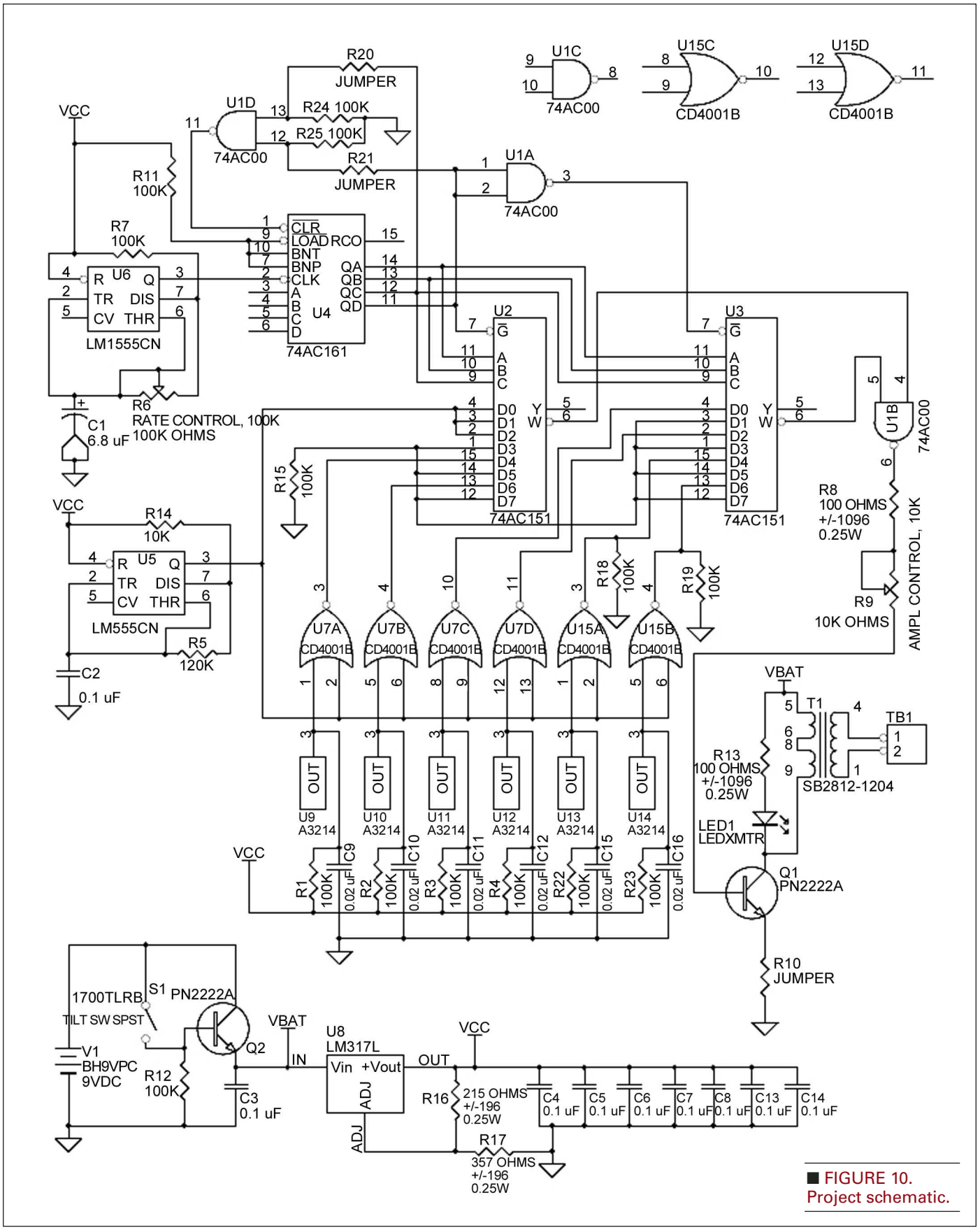
The enhanced kit version's LED is a Fiber Optics, Inc., IF-E96. This visible red LED has a "connector-less" style fiber optic package per the manufacturer. The LED's output peaks at 660 nm, as previously mentioned. The internal micro-lens and precision molded housing maximizes coupling through extremely precise collet alignment of the LED into a standard 1,000 µm core plastic fiber cable (which the kit provides). Figure 8 is a cross-sectional view of this device that is ideal for this "magical" application. You can screw the threaded collet open and shut. This allows you to insert the optical fiber, abutting it to the micro-lens which is between it and the red LED.

Collets and chucks are closely

■ FIGURE 8. A cross sectional view of the IF-E96 LED optical fiber holding module. Artwork courtesy of Industrial Fiber Optics, Inc.



■ FIGURE 9. The Bivar Model FLPR-SR alternate optical fiber holding module.



■ FIGURE 10. Project schematic.

■ FIGURE 11. The Bivar HandyPro Fiber Cutter™ from BivarOpto.

related. Both are cone-shaped sleeves that you use to hold a circular or rod-like piece in a lathe or machine. Typically, you center a tool in a holding fixture with a collet. (A collet's opening range is more limited than a chuck.) Here it holds and very exactly centers an optical fiber in your securing and alignment fixture.

Alternate Light Source

The PCB (printed circuit board) accommodates a variety of second-source parts. There is an alternate equivalent light source — the Bivar model FLPR-SR "flexible light pipe base" (Figure 9). It securely holds an optical fiber, has an internal micro-lens, and uses a slightly darker red LED. There are no nubs on this for strain relief like the IF-E96, so it comes with a cable tie to loop through these holes, serving as a strain relief to secure the FLPR-SR. Refer to the schematic in Figure 10 to see where the LED goes.

If you ever damage and need a new plastic optical fiber, or even want to reduce the service loop length, you can cut this cable with an ordinary razor. However, if you have several thousand cables to cut like we did, try the new, inexpensive palm-sized HandyPro Fiber Cutter™ from BivarOpto (the optoelectronics division of Bivar, Inc.) shown in Figure 11. Its design cuts or strips plastic optical fiber (POF) and flexible light pipe (FLP) cabling. It's made of molded ABS plastic, and measures only 1.75" x 1.12." Its internal stainless steel blade accurately cuts one mm and two mm fibers, including native or sheathed fiber, or glass cabling.

■ FIGURE 13. Stacking magnets with contiguous North to South poles.

You strip POF or clad fibers by rotating the cutter around the fiber. This smoothly scores the sheathing without cutting or damaging the native fiber inside. Be careful to apply even pressure to the upper section of the cutter to ensure precise and smooth cutting, before you insert the fiber into the light source.

(Don't) See the Light

The light source is cleverly disguised because it can only be viewed through a minute pinhole. Use a dark brown or black felt tip pen to darken around the outside of the pinhole so nobody sees this drilled hole. It purposely has a very narrow columnated field-of-view, so only you know where it is. You can only see this light by strategically placing your thumbnail against it.

We suggest you place both of your hands palms down on either side of the box with fingers slightly curled under. Slightly point your thumbs inward so your thumbnail is obscured by the remainder of your hand. Look carefully at Figure 12 and try to see the pinhole. This very faint light illuminates your thumbnail, allowing you to decipher periods of alternating long and short durations of light — resembling an optical Morse code.

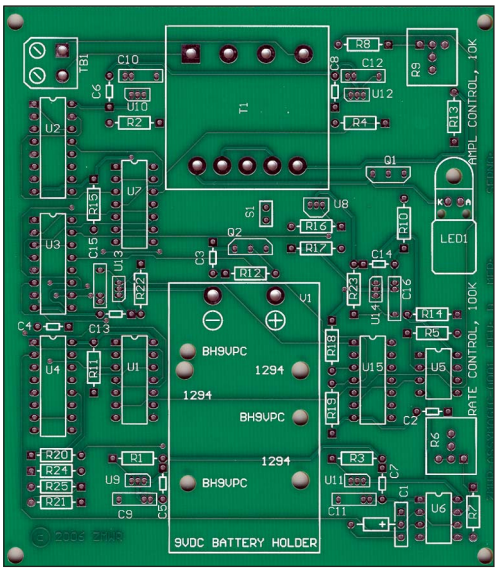
■ FIGURE 12. The suggested sleight-of-hand positioning.

Design Notes and Tips

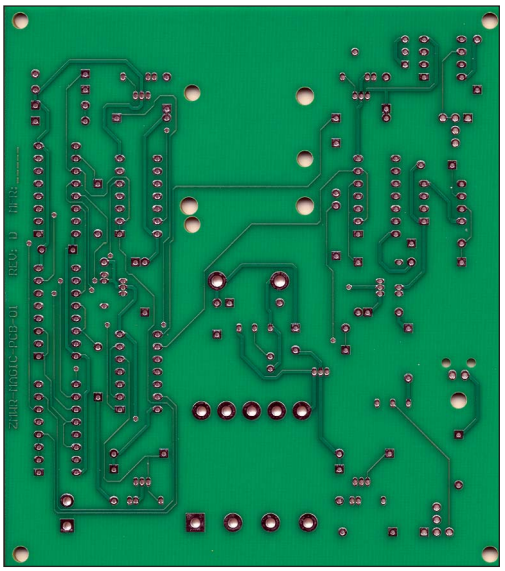
When you insert the magnets into the pawn's bases, we suggest you start by stacking all of the magnets in a column (Figure 13). "Peel" each magnet off the bottom of the stack when inserting them in the pawns. That will keep the finished pawns from having a North to South pole touching one another. If you allow North to South poles to touch, they will strongly attract one another and give away your secret. Even though the Hall Effect sensors in this project are not pole dependent and will work with any pole orientation, this method is a good practice.

Establish a consistent pattern to determine the missing pawns based on your battery placement. If you position the battery pointing to the right, the pawn numbering sequence corresponds to Figure 2. (This is for either the four or six pawn version.) If you place the battery to the left, you literally invert the numbering sequence. We recommend only placing the battery on the right so the tilt ON/OFF switch works when you rest it on the back hinges. This switch is either an open or short driving the base of a transistor (refer again to Figure 10).

This project has one dual-sided PCB with plated through holes and silk-screened component outline silhouettes which accommodates both the basic and enhanced versions. (See Figures 14 and 15 for the board's component and wiring



■ FIGURE 14. The PCB's component side.



■ FIGURE 15. The PCB's wiring side.

sides, respectively.) It also accepts various style pots, capacitors, and two different nine-volt battery holders without any modifications. There are six mounting holes on the PCB for the battery holder, but you will only use three of them. There are three holes with BH9VPC and three with 1294 silk-screened beside them on the PCB included in the kit. They indicate where you place three nylon screws and nuts for one or the other of the battery holders.

During assembly, you'll need a fine tip soldering iron (the smaller, the better), solder, cutter pliers, needle-nose pliers, a hair dryer to heat the shrink tubing, a very small hammer, and a Phillips screwdriver.

It would be helpful to have a DMM with a built-in frequency counter or an oscilloscope, however, you can build the project without them, albeit with a greater degree of difficulty in the troubleshooting and testing stages.

Be prepared for tight soldering requirements from 0.050" lead spacing on the Hall Effect sensors, as well as on the voltage regulator. The sensors (Hall Effect and tilt) go on the traditional "non-component" wiring side of the PCB.

If you'd like to make your own box, it will require a "cradle" for supporting the acrylic sheet, top panel, and PCB. Be certain to use hardwood for the top panel since it has to take four wood screws that might otherwise crack a soft wood. It should closely conform to the dimensions of Figure 16. This is the supporting frame (or struts) upon which the electronics assembly with the acrylic sheet and wooden top panel rests. The second part of the drawing shows how all of it fits together. The three Escutcheon pins on each side are 5/8" long, #18 (.049" shank diameter) brass brads or miniature nails. Ensure that you drill a hole with a 1/4" Forstner bit (see Figure 17). This allows the extended shaft shoulder washer (Figure 18) to lay flat and flush with the right cradle member's surface. This enables it to securely hold the optical fiber.

More extensive drawings for building your own box are available for download on the *Nuts & Volts* website (**www.nutsvolts.com**).

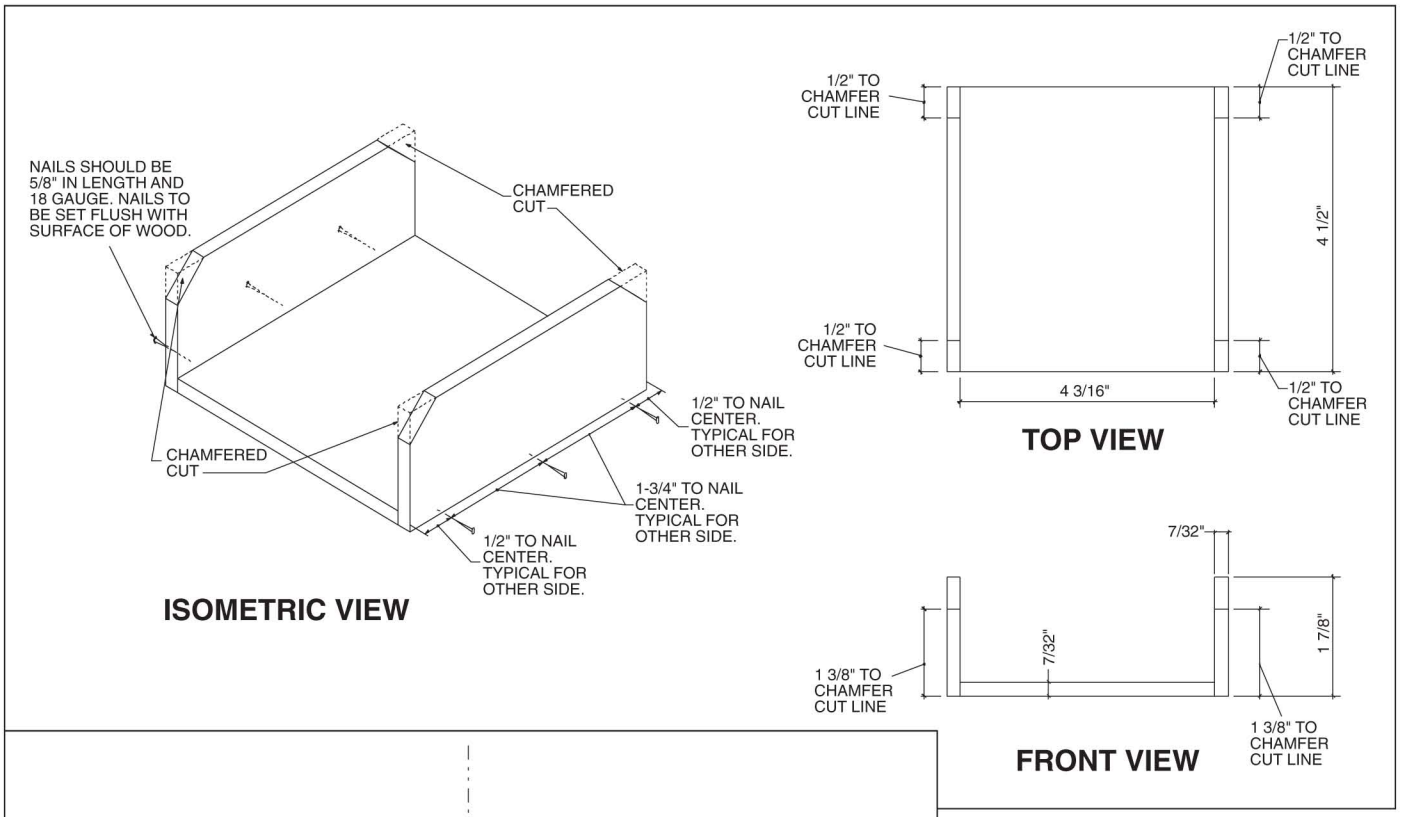
The Hall Effect Sensor ICs

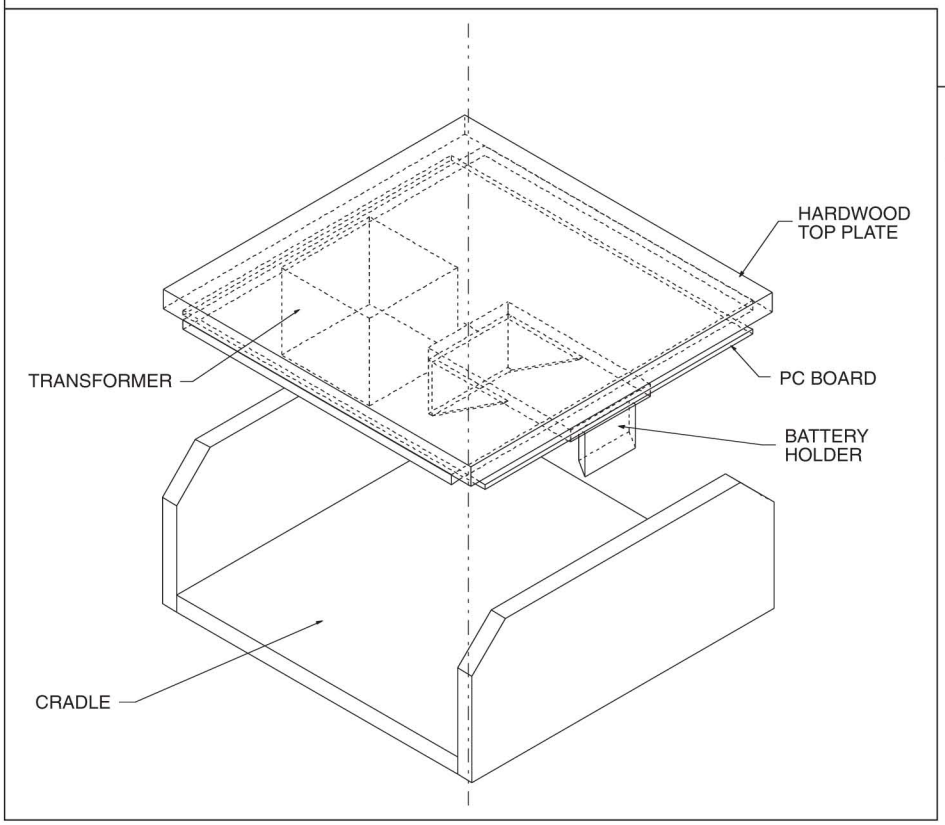
The ICs we used are Allegro Microsystems A3214 micro-power,

Pinhole Light Theory

If you are intrigued or baffled by how a small ray of light emanating from a pinhole casts itself most sharply on your thumbnail at a given distance, but otherwise diffuses into space, you might want to examine the underlying theory of operation of pinhole cameras. First — unlike a traditional camera — a pinhole does not focus light as a lens does. If you change the pinhole to your thumbnail distance (focal length), it has little effect on image sharpness. However, when you critically examine the light cast upon your thumbnail, you will discover there is an optimum pinhole diameter for any given pinhole-to-focused-plane distance.

If you increase the size of the pinhole from this optimum hole diameter, it passes more light through but it also degrades image sharpness. Generally, making the hole smaller increases image sharpness. If you are a photographer, you already realize that decreasing the iris diameter increases the depth-of-field or allows you to have both near and far images alike more in focus. Decreasing the pinhole size does not necessarily increase image sharpness. This is because you may have decreased its size beyond this optimum diameter for the specified distance; diffraction sets in, which decreases image sharpness. Go to **www.pinholephotography.com.au/Theory/theory.html** The optimum pinhole diameter is approximately 1/25th the square root of the distance between the pinhole and the object upon which the light is cast. In our example, using a 1/16" drill would give you an impractical optimum distance of 1.44 inches. This is impractical because you would not want to have your thumbnail any greater than 1/4 inch from the pinhole to conceal it from a skeptical observer trying to discredit your trick. Obviously, this means that to be in focus, your thumbnail has to be virtually right next to the LED light source.





■ FIGURE 16. A dimensioned mechanical drawing of the "cradle."

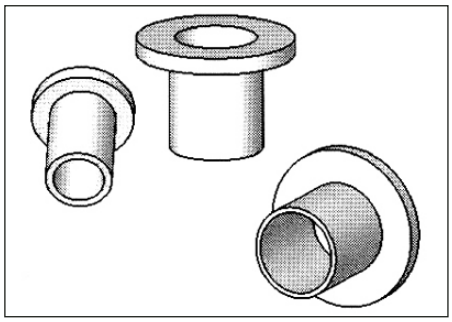
ultra-sensitive Hall Effect switches that are pole independent. This means they can switch on or respond to either a North or South pole magnet of sufficient strength. (This characteristic is ideal for the small 1/4" diameter magnets supplied in the kit.) Otherwise, you would have no convenient way of distinguishing one pole from the other. The manufacturer accomplishes pole independence with dual comparators after the amplifier, but before the parallel Schmitt triggers (see Figure 19).

In the absence of a magnetic field, this sensor's output is off. Incidentally, the A3211 is a member of this 3211, 3212, 3213, and 3214 family. However – unlike its brethren – this IC provides a non-inverted output. It exhibits a logic high in the presence of a sufficiently strong magnetic field. The other ICs have normal logic low outputs in the presence of a magnetic field.

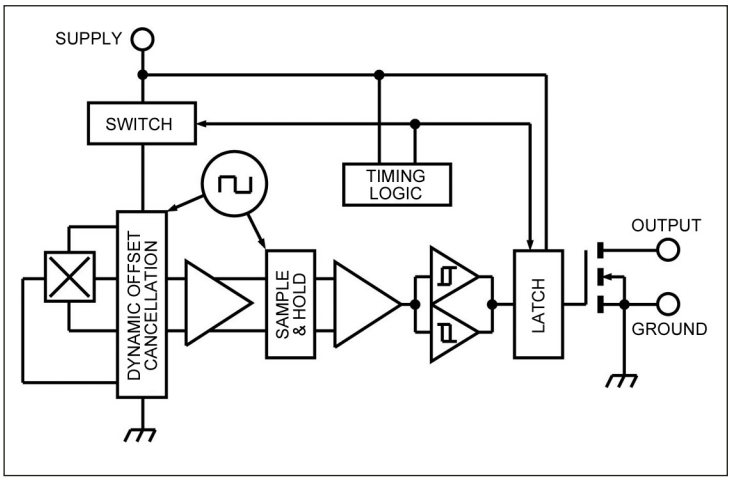
Low Average Power

Internal timing circuitry activates the sensor for 45 µs and deactivates it for the remainder of the period (45 ms). A short "awake" time allows for stabilization prior to the sensor sampling and data latching on the falling edge of the timing pulse (Figure 20). The IC latches the output during the "sleep" time in the last sampled state. The output state

■ FIGURE 17. A Forstner bit.



■ FIGURE 18. An extended shaft shoulder washer. Artwork courtesy of Richco Plastics.



■ FIGURE 19. A block diagram of the Hall-Effect sensor showing parallel Schmitt Triggers. Artwork courtesy of Allegro Microsystems.

does not affect the supply current and this overall scheme greatly conserves power.

Chopper-Stabilizing Technique

You can best visualize the Hall element as a resistor array similar to a Wheatstone bridge. A large portion of the offset results from resistor mismatching. The kit's sensors use a proprietary dynamic offset cancellation technique, with an internal high-frequency clock to reduce the residual offset voltage of the Hall element that is normally caused by device over-molding, temperature dependencies, and thermal stress (see Figure 19 again).

The chopper-stabilizing technique cancels the mismatching of the resistor circuit. It does this by changing the direction of the current flowing through the Hall plate using CMOS switches and Hall voltage measurement taps. It accomplishes this while maintaining the Hall voltage signal that is induced by the external magnetic flux.

The sample-and-hold circuit then captures the signal and further processes it using low-offset bipolar circuitry. This technique produces devices that have an extremely stable quiescent Hall output voltage, are immune to thermal stress, and can precisely recover after temperature cycling. This IC uses a relatively high sampling frequency for faster signal processing capability.

Just What Is the Hall Effect?

The Hall Effect describes a particle with charge Q at velocity V, moving within a magnetic field B, and its experienced Lorentz Force (see Figure 21a). This amasses electrons on one side, creating a voltage proportional to the magnetic field (see Figure 21b). When an electric charge moves through a magnetic field, there is a force on the charge, perpendicular to the direction of the charge and perpendicular to the direction of the magnetic field. (This is the Lorentz Force.) This also applies to electric current in a wire.

Take your right hand with your thumb up, your forefinger or first finger forward, and your second finger perpendicular to the other two per the current within the wire in Figure 22. This shows the field directions per the Right Hand Rule. Many industrial products that you may not even realize capitalize on this and use Hall Effect sensors (see Figure 23).

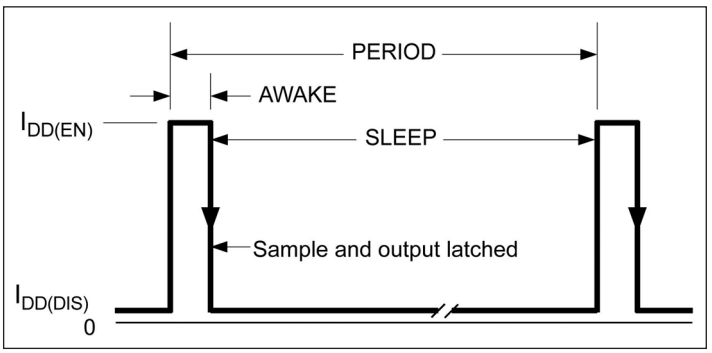
You could use an A3211 Hall Effect sensor with its inverter logic output and just substitute the CD4001 NOR quad gate IC for the CD4011 NAND quad gate IC. The logic here will also be inverted to match the A3211's inverted logic. It should work just fine (see Figure 24), noting that these opposite polarity waveforms act as if you run one through an inverter to get the other.

When you open and close your cell phone, it miraculously turns on and off automatically. It does so by activating a Hall Effect sensor near its hinge. This is very similar to what this project does.

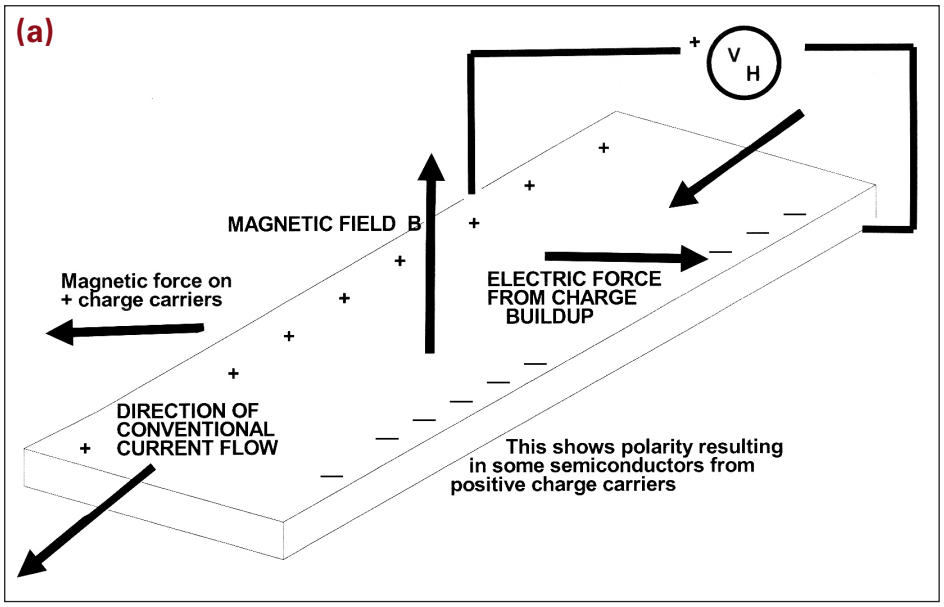
The A3212, A3213, and A3214 are all virtually identical with the exception of the latter two having a wider operating voltage range to 5.5 volts. Each successive product improves in sensitivity and uses less power.

Hall Effect Sensor Tradeoffs

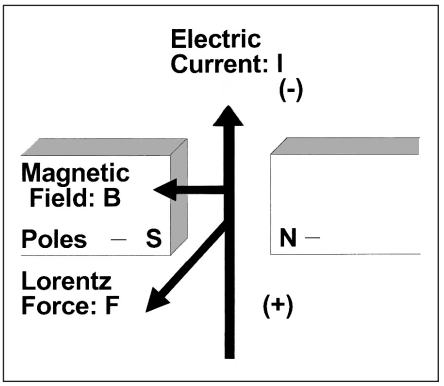
These useful characteristics come



■ FIGURE 20. The sensor allowing for stabilization prior to the sampling and data latching on the falling edge of the timing pulse. The output latches during the "sleep" time in the last sampled state. Artwork courtesy of Allegro Microsystems.



■ FIGURE 21. (a) The forces governing a particle moving within a magnetic field associated with the Hall Effect phenomenon. (b) Electrons amassed at one side of a conductor due to the Hall Effect.



■ FIGURE 22. The Lorentz Force and how it relates to the Right Hand Rule.

at a price — the most notable is limited power supply range; they lack an internal voltage regulator. The manufacturer strongly recommends that you also use two external bypass capacitors in close proximity to the Hall sensor. Strategically locate the larger one between the voltage supply and ground pins (see Figure 25). Locate the smaller one at the sensor's output. This reduces both external noise and noise generated by the chopper-stabilization technique inherent in this IC's design.

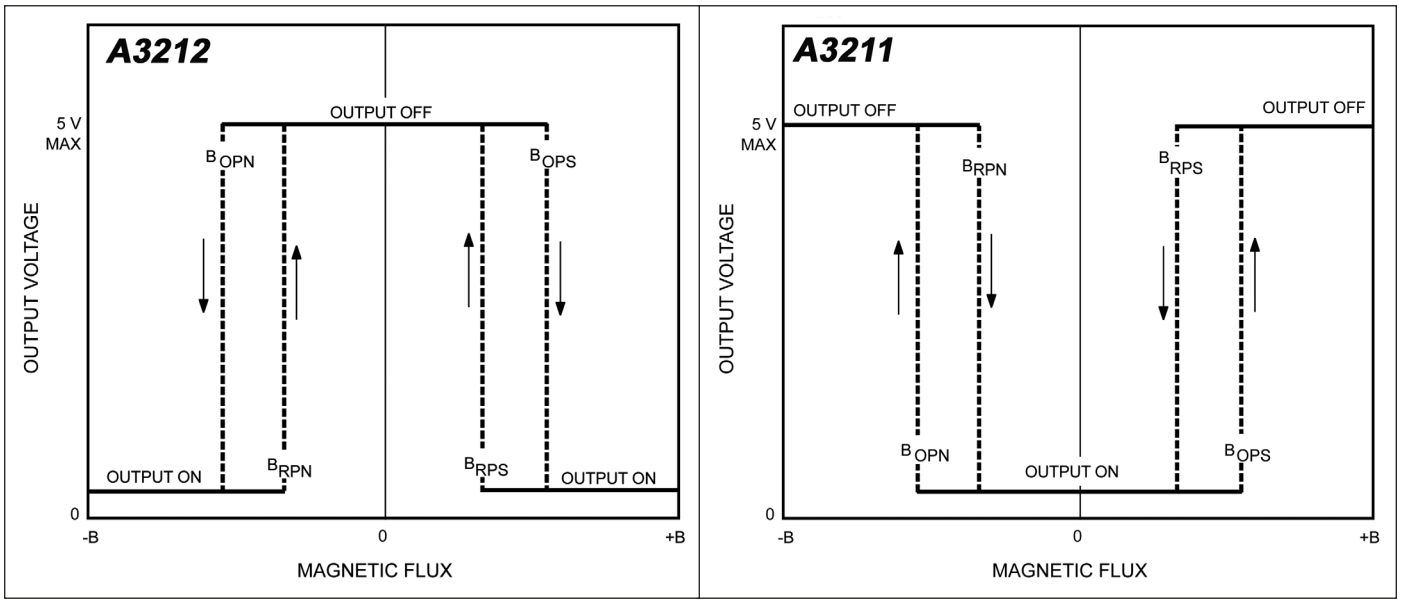
This device includes a Hall voltage generator, small-signal amplifier, chopper stabilization, a latch, and a MOSFET output on a single silicon chip. This IC takes advantage of advanced BiCMOS processing for low voltage and power requirements, component matching, very low input offset errors, and small component geometries.

The presence of transients on the line would have necessitated additional circuitry, as well as guarding against reverse battery insertions. But no transients exist since this project runs off a battery with no severe spikes from switching heavy loads. Power polarity reversal issues disappear since the 9 VDC battery is a NEMA 1604 standard battery with one male and one female terminal at its ends, making reverse insertion into this project's battery holder an impossibility (see Figure 26).

■ FIGURE 23. Various applications using Hall Effect sensors. Artwork courtesy of Sypris Test & Measurement.

Powering Up and Low Duty Cycle

On powering up, this device starts sampling after 90 ms and does so at less than a 1% duty cycle; again, another inherent characteristic to conserve energy. The A3214 is an improvement over its sister IC — the A3210 — in power consumption, magnetic switch points, and extended



■ FIGURE 24. The A3211 Hall Effect sensor and its opposite polarity brethren, the A3212. Artwork courtesy of Allegro Microsystems.

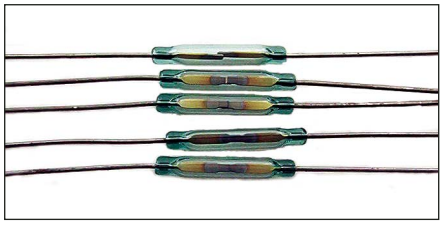
temperature range. The maximum average supply current of the A3214 is 10 µA at 2.75 V, compared to 25 µA for the A3210.

As the numbers in this series increase, these crucial parameters also improve with each new offering. Its switching points are also tighter, allowing for operating in a weaker magnetic field, while compensating for magnetic noise created by extraneous sources such as cellular phone speakers or computer hard drives.

Drop-in Reed Switch Replacement

This Hall Effect IC offers another advantage: It is a virtual drop-in replacement for reed switches. In fact, our original design used reed switches but we were dismayed at how sensitive they were with respect to pole dependence. It also required a larger magnet to provide sufficient force to reliably activate them. Reed switches are far more delicate with a greater tendency to have the electrodes break away from the glass body of the case housing them (see Figure 27). This IC has no electro-mechanical contacts since it is all solid-state.

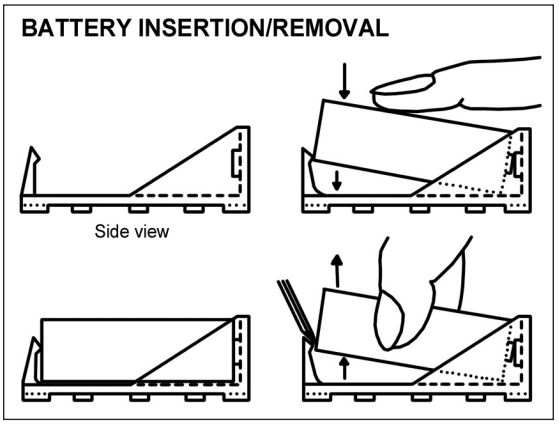
■ FIGURE 27. A notoriously unreliable glass encapsulated magnetic reed switch.



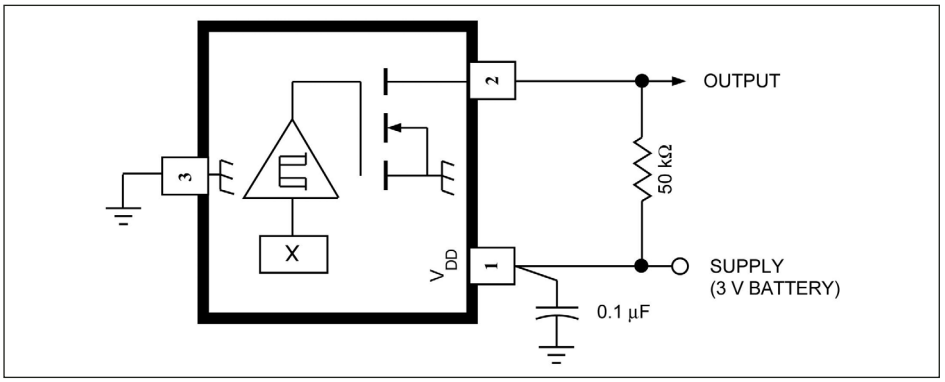
A Multiple Purpose Pattern

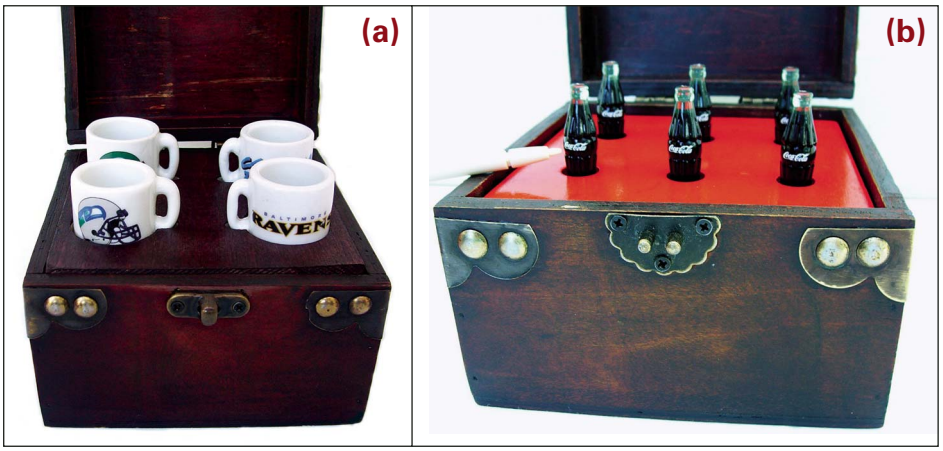
A paper mask placement/sensor alignment pattern comes inside the box included in each kit. The pattern serves two purposes. The large circles are for proper adhesive

■ FIGURE 26. Inserting and/or removing the 9 VDC battery into its battery holder case.



■ FIGURE 25. Placing the 0.1 µF or 0.02 µF capacitor as closely as possible to the Hall Effect sensor's supply voltage pin and ground. Artwork courtesy of Allegro Microsystems.





■ FIGURE 28. (a) Miniature porcelain mugs with NFL labels on their sides. (b) The project using miniature Coca Cola™ bottles instead of pawns.

PARTS LIST

ITEM	DESCRIPTION
Passives (all resistors are 1/4 watt 5% unless stated otherwise)	
❑ R1, R4, R7, R11, R12, R15, R18, R19, R22-R25	100K
❑ R5	120K
❑ R6	100K rate control pot (various suppliers)
❑ R8, R13	100Ω
❑ R9	10K amplitude control pot (various suppliers)
❑ R10, R20, R21	Onboard jumpers
❑ R14	10K
❑ R16	215Ω, 1%
❑ R17	357Ω, 1%
❑ C1	6.8 µF tantalum polarized capacitor
❑ C2-C8, C13, C14	0.1 µF capacitor 0.25" spacing (various suppliers)
❑ C9-C12, C15, C16	0.01 or 0.02 µF capacitor 0.2 or 0.25" spacing (various suppliers)
Semiconductors	
❑ U1	74AC00
❑ U2, U3	74AC151
❑ U4	74AC161
❑ U7, U15	CD4001B
❑ U5, U6	LMC555CN
❑ U8	LM317LZ
❑ U9, U10-U14	A3214LUA SOT package (Digi-Key P/N A3214LUA-ND)
❑ LED 1	LEDXMTR blue LED or Industrial Fiber Optics P/N IF-E96 (Digi-Key P/N FB128-ND)
❑ Q1, Q2	PN2222A
Misc.	
❑ S1	SPST tilt switch, metal case two-lead (Electronix Express Rollerball P/N 1700TLRB)
❑T	2 VA CT transformer, like Tamura SB2812-1204 (Digi-Key P/N MT7249-ND)
❑TB1	2 pin .197" (5mm) Euro terminal block (Jameco P/N 164793)
❑Two #6 stud ring terminals, 22-16 AWG	(Jameco P/N 103684)
❑ 9 VDC battery holder	(Digi-Key P/N BH9V-PC-ND)
❑ Six or four pawns with six or four magnets and felt self adhesive pads	
❑ Metallic hardware	
❑ 19 pieces of plastic hardware	

Notes
For the six pawn enhanced version, delete R18-R21. For the basic four pawn version, delete C13-C16, R22-R25, and U13-U15. Both kits, the PC boards alone, or the boxes alone, are available from the authors at **www.zonemasterskits.com**.

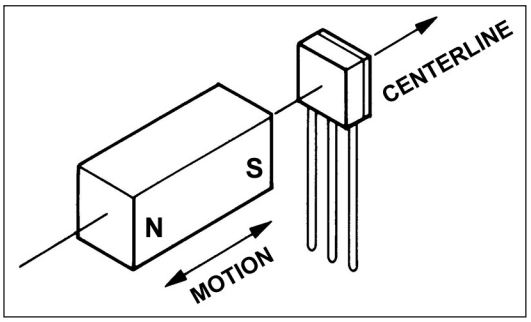
paper mask alignment (to be discussed in the assembly section in Part 2). This prevents anyone from seeing through the acrylic sheet and discovering that there are actually electronics below the pawns.

This pattern also helps you align the sensors exactly beneath the magnets that activate them. (If the noncontiguous numbering and placement pattern appear unorthodox to you, it's because it has to accommodate both the four and six pawn kit versions.)

If you elect to substitute something else for the pawns as the magnet holding devices, the provided pattern will help with alignment. Check out a couple variations in Figure 28. Remember, the sensors must reside exactly below the cross-hairs for the most reliable Hall Effect sensor activations. Figure 29 demonstrates the proper inline path with a magnet.

More Pointers

In case you have an overly attentive observer, as a back-up plan, you can move the ball bearing with the magnet; refer to Figure 30. This tilt sensor/switch illustration shows the roller ball bearing inside the cylindrical case. It allows movement within and activation



■ FIGURE 29. The proper inline path of a magnet approaching a Hall-Effect sensor.

occurs at approximately a 15 degree inclination. As it makes contact with the two internal terminals, it completes the circuit and allows base drive to the transistor.

If the switch happens to be in its normal ON position (not tilted), this gives you an option other than the tactile tingling to foil trick busters.

If the tingling sensation in the tactile method is too intense, there is a pot to control this. The words AMPL CONTROL, 10K are silk-screened on the PCB next to this pot. It allows you to decrease the intensity of the tingling. The LED's output is in parallel with this circuit, so you will simultaneously decrease the LED's brightness. The other 100K pot has a RATE CONTROL, 100K silk-screen nomenclature. You use this to control the speed at which the flashing LED progresses through the long followed by four or six short periods — minus, of course, the missing pawns' pulse or pulses.

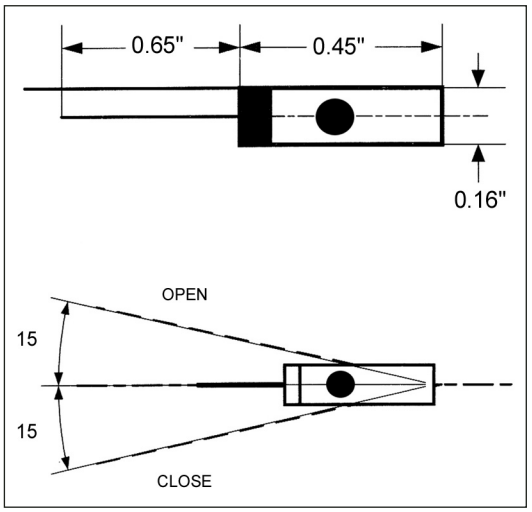
The Voltage Regulator

The LM317LZ adjustable positive voltage regulator is a monolithic integrated circuit that comes in a TO-92 plastic package with the kit. It has both overload and short circuit protection. It can supply up to 100 mA of load current with an output voltage adjustable over a 1.2 to 37V range. You select the nominal output voltage by a resistive divider derived from a pair of resistors — RX and RY (see Figure 31, the voltage regulator's pinout pattern). The output voltage formula is:

FORMULA 1:

$$V_{OUT} = V_{REF} (1 + R_Y/R_X) + I_{ADJ} R_Y$$

I_{ADJ} is 100 µA. The LM317LZ provides an internal reference voltage of 1.25V between the output and adjustment terminals. Therefore, V_{REF} in Formula 1 above is a nominal 1.25 volts. Resistors R_X and R_Y in this project are 215 Ω and 357 Ω, 1% 1/4W resistors to ensure an output voltage very close to 3.35 volts. Figure 32 is actually a spreadsheet calculation showing the possible voltage limits, considering all possible variables. If you plug the values of these resistors into Formula 1, you will arrive at an approximate value of 3.35 volts. This is an ideal supply voltage for the Hall Effect sensors and the CMOS logic. This low voltage ensures current consumption to prolong battery life.

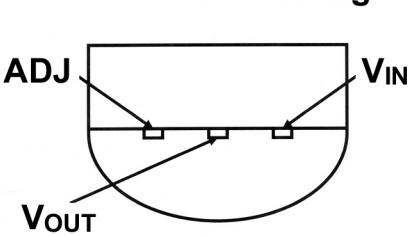


■ FIGURE 30. The tilt sensor's outline drawing, showing its internal ball bearing.

Proper Component Insertion

The two largest components are the transformer and the battery holder. The transformer has four terminals on one side and five on the other, making it impossible to install it wrong onto the PCB. The battery holder is also impossible to install improperly due to its shape and a silkscreen pattern showing its exact placement.

Next month, we'll cover the project's theory of operation, assembly, testing, and examine the Hall Effect phenomenon and magnetism. **NV**



■ FIGURE 31. The LM317LZ voltage regulator's pinout assignments.

Vref	R1	R2	Vout	R1+R2	R1+R2 @10ma Min	R1+R2 @5ma Min	
1.20	215	357	3.19256	572	319.26	638.51	
1.25	215	357	3.32558	572	332.56	665.12	
1.30	215	357	3.45860	572	345.86	691.72	
	-1%	+1%					
1.20	212.85	360.6	3.23281	573.42	323.28	646.56	
1.25	212.85	360.6	3.36751	573.42	336.75	673.50	
1.30	212.85	360.6	3.50221	573.42	350.22	700.44	EXTREMA
	+1%	-1%					
1.20	217.15	353.4	3.15310	570.58	315.31	630.62	EXTREMA
1.25	217.15	353.4	3.28448	570.58	328.45	656.90	
1.30	217.15	353.4	3.41586	570.58	341.59	683.17	

■ FIGURE 32. The LM317LZ voltage regulator's calculated voltage extremes.

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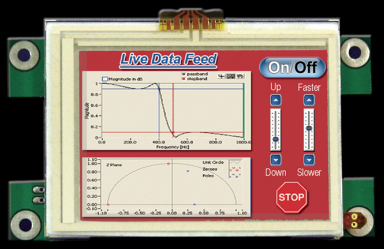

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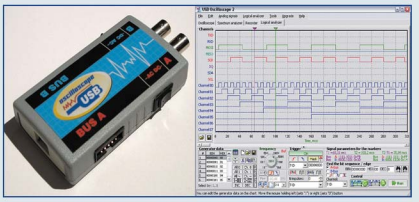

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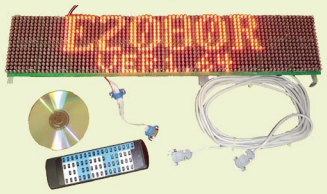

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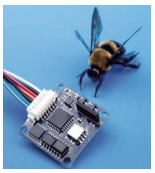

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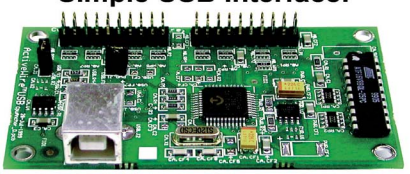

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Continued from page 45

NEWS BYTES

WORLD'S FIRST DISHWASHER SAFE KEYBOARD AND MOUSE

Seal Shield Corporation has unveiled their new signature products, the SEAL SHIELD™ Medical Grade Washable Keyboard and Mouse. According to the company, the SEAL SHIELD Keyboard and Mouse are the first ever to be fully submersible and dishwasher safe.

Seal Shield's products have been developed in response to the demand from healthcare organizations for disinfectant solutions to combat the spread of cross contamination infections. This year, over two million patients will contract an infection while seeking treatment in a US hospital. Of those, close to 100,000 people will die, making hospital acquired infections a top-10 killer. Complicating this epidemic, a strain of antibiotic resistant staph infections (MRSA) has emerged in hospitals worldwide.

The recent rise in hospital acquired infections and the lack of an effective treatment for MRSA has prompted healthcare providers to reexamine their cleaning protocols in an effort to reduce cross contaminations. In response to the demand from major hospitals, Seal Shield has developed a family of common computer input devices which can be disinfected and washed to prevent the spread of bacterial infection.

Recent studies have shown the computer keyboard and mouse to be a major source of cross contamination infections. According to Dr. Daniel LePera, "Bacteria that reside in the upper mouth or respiratory tract can travel to an in-office computer keyboard and survive as long as 24 hours. Viruses can live on them for one hour or more."

Previous attempts to properly clean and disinfect keyboards have proven ineffective due to the keyboard's electronic circuitry. Existing solutions have either been cost-prohibitive or unreliable. Even so-called "spill proof" or "washable" keyboards have been shown to be ineffective. Although those products may be water resistant to a point, they are not fully submersible and not dishwasher safe.

"The SEAL SHIELD Medical Grade Washable Keyboard and Mouse are the only solutions which are fully submersible and dishwasher safe. Our products have been designed for healthcare, but are aggressively priced for the mass market," states Bradley Whitchurch, Chief Executive Officer at Seal Shield. "SEAL SHIELD Medical Grade washable input devices, combined with effective cleaning protocols, represent a proven and economical solution for reducing hospital infection rates."

For more information about SEAL SHIELD products, visit **www.Seal Shield.com**.

NEWEST MEMBERS OF PIC FAMILY

Microchip Technology, Inc., is now offering a new 12-member PIC18F87J11 general-purpose, high-performance eight-bit microcontroller family, which has up to 20% greater performance with 12 MIPS (48 MHz), enhanced peripherals, and lower sleep power consumption. With its breadth of family members, the PIC18F87J11 also provides a wide range of program memory and peripherals, ranging from most cost effective to feature rich.

Microchip (**www.microchip.com**) is expanding its 3V PIC18F J-series of eight-bit microcontrollers to address cost-sensitive markets requiring high performance. Additionally, the PIC18F87J11 general-purpose family includes nanowatt technology for low power consumption in sleep mode — as low as 100 nA — which is ideal for battery-powered applications. Finally, the PIC18F87J11 is the first eight-bit microcontroller to offer the Parallel Master Port for connection to external memory and displays.

Consumer and industrial applications include: wireless Internet-enabled appliances, hands-free cell phone adapters, white good appliances, game controllers, cappuccino machines, two-way pagers, TCP/IP interfaces, home-alarm/security-system keypads, server power-supply and temperature controllers, power-meter hubs, security panels, data logging, and central AC communication controllers. **NV**

USB for *Projects on a Budget*

by Jan Axelson

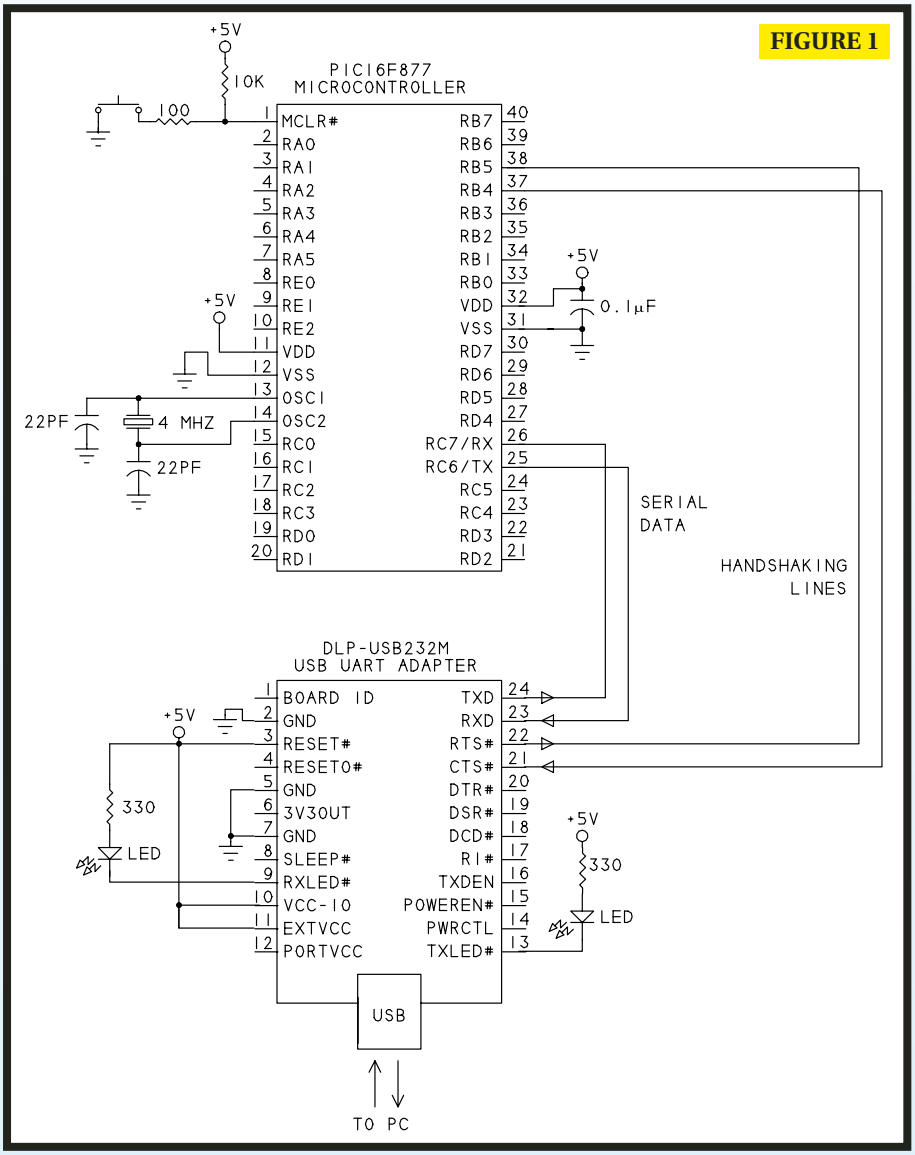


FIGURE 1

Adding a USB interface to a device can seem like a daunting task. Every USB device must contain device-controller hardware and must have a software driver in the PC. Many options exist for device controllers and drivers, and the right choices can make a big difference in how quickly you get a project up and running.

This article shows three ways to add USB to devices. Each takes a different approach, but all are suitable for devices built in small quantities and on limited budgets. For a review of USB technology, see the USB in Brief sidebar.

USB Virtual COM Port

For years, every PC came with one or more RS-232 serial ports. Software accesses these ports as numbered COM ports (COM1, COM2, and so on). But not every COM port has an RS-232 interface. Some devices with USB ports can function as virtual COM ports.

Applications access virtual COM ports in the same way as RS-232 ports. Users can communicate using terminal-emulator software such as Windows Hyperterminal. Programmers can use the SerialPort class in Microsoft's .NET Framework. The only difference is that the hardware interface is USB instead of RS-232. Lower-level drivers handle the details of accessing the hardware.

Virtual COM ports provide a way to

If you have an idea for a device that communicates with PCs, the chances are good that the device will connect to the PC via the Universal Serial Bus (USB). You're probably well acquainted with USB as the interface used by mice, keyboards, drives, cameras, and other mass-market peripherals. But USB is also versatile enough for use in specialized devices produced in single or small quantities.

transfer data for just about any purpose. If you're familiar with COM-port programming or have existing COM-port code you want to re-use, a virtual COM port can be a good choice. The COM-port data travels in USB's bulk transfers, so transfers are fast on a bus that isn't busy.

A virtual COM-port device can use a generic USB-capable controller chip or a special-purpose controller designed for use as a virtual COM port.

A popular special-purpose controller is FTDI Chip's FT232BM USB UART. The chip is a USB/asynchronous serial converter that manages all USB communications in hardware. You don't have to know anything about USB protocols to use this chip. For experimenting, DLP Design (**www.dlpdesign.com**) offers DIP adapter modules that each contain a controller chip, USB connector, and related components.

You can interface the USB UART to just about any microcontroller or other CPU that has a UART or USART for asynchronous serial communications (Figure 1). On enumeration, the PC assigns FTDI Chip's (free) drivers to the chip. The drivers cause the chip to appear as a COM port on the PC. You can set the baud rate and other parameters for the chip's asynchronous port just as you would for an RS-232 port.

When a PC application writes a byte to the virtual COM port, the USB UART receives the byte at the chip's USB port and passes the byte to the chip's asynchronous serial port using the selected port parameters. A microcontroller that connects to the serial port can read the received byte. In the other direction, when the microcontroller writes a byte to its serial port, the USB UART receives the byte as serial data and passes the byte to the PC via USB. COM-port software on the PC can retrieve the received byte.

If you prefer a parallel interface to your microcontroller, FTDI Chip's FT245BM USB FIFO chip has a bidirectional parallel interface instead of a serial interface. PC applications can access the chip as a COM port and exchange data with the chip's parallel port. (The baud rate and other serial-port parameters don't apply.)

Rather than using a special-purpose USB controller and drivers, another option is to use a general-purpose controller and the USB COM-port driver included with Windows. With this approach, the microcontroller and USB controller can reside on the same chip.

Because of performance and other problems with earlier driver editions, it's best to use the included USB COM-port drivers only with Windows XP Service Pack 2 (SP2) or later Windows editions. Microchip Technology and Atmel Corporation provide complete example firmware for USB COM-port devices that use the built-in Windows drivers.

Generic Human Interface Device

If you want to use drivers included with Windows, another option for USB devices is the Human Interface Device (HID) class. Keyboards, mice, and game controllers are HIDs, but you can also design generic HIDs that transfer data for any purpose.

PC applications communicate with HIDs using Windows API functions such as CreateFile, ReadFile, and WriteFile, as well as APIs that are specific to HIDs. The .NET Framework doesn't provide a HID class, but .NET applications can call API functions. The HIDmaker software from Trace Systems, Inc. (**www.tracesystemsinc.com**), can automate much of the task of writing PC software for any HID and writing code for Microchip controllers.

All HID data travels in structures called reports. A report descriptor in the device defines the size and direction of each report (Listing 1). An Input report travels from the device to the PC. An Output report travels from the PC to the device. A Feature report can travel in either direction. The reports can contain data for any purpose.

HIDs use USB's control and interrupt transfers. The maximum guaranteed bandwidth using the Windows drivers is 64 kilobytes/sec per endpoint. Even at high speed, the default interface should request no more than 64 kilobytes/sec and supporting an alternate interface would require a custom driver.

Many device manufacturers provide HID examples. A mouse or keyboard example can provide a good head start for creating a generic HID.

Using a Generic Driver

A third option that can be useful for any specialized device is using a generic driver. The driver defines functions that enable PC applications to exchange data with the device. The downside to using a generic driver is

LISTING 1

This HID report descriptor defines three two-byte reports.

```
0x06  0xFFA0     Usage Page (vendor defined)
0x09  0x01       Usage (vendor defined)

0xA1  0x01       Collection (Application)

The Input report

0x09  0x03       Usage (vendor defined)
0x15  0x00       Logical Minimum (0)
0x26  0x00FF     Logical Maximum (255)
0x95  0x02       Report Count (2)
0x75  0x08       Report Size (8 bits)
0x81  0x02       Input (Data, Variable, Absolute)

The Output report

0x09  0x04       Usage (vendor defined)
0x15  0x00       Logical Minimum (0)
0x26  0x00FF     Logical Maximum (255)
0x75  0x08       Report Size (8 bits)
0x95  0x02       Report Count (2)
0x91  0x02       Output (Data, Variable, Absolute)

The Feature report

0x09  0x05       Usage (vendor defined)
0x15  0x00       Logical Minimum (0)
0x26  0x00FF     Logical Maximum (255)
0x75  0x08       Report Size (8 bits)
0x95  0x02       Report Count (2)
0xB1  0x02       Feature (Data, Variable, Absolute)

0xC0             End Collection
```

LISTING 2

Every USB device contains a device descriptor with a Vendor ID and Product ID that identify the device.

```
Device Descriptor

0x12                    Descriptor size in bytes
0x01                    Descriptor type (Device)
0x0200                  USB Specification release number (BCD) (2.00)
0x00                    Class Code
0x00                    Subclass code
0x00                    Protocol code
0x08                    Endpoint 0 maximum packet size
0x0925                  Vendor ID (Lakeview Research, assigned by usb.org)
0x1234                  Product ID (assigned by vendor)
0x0100                  Device release number (BCD)
0x01                    Manufacturer string index
0x02                    Product string index
0x03                    Device serial number string index
0x01                    Number of configurations
```

that you're likely to be dependent on the driver's provider to fix any problems.

Although you can write your own driver, Windows driver writing isn't an easy task and thus isn't worth pursuing for most small-quantity projects. Fortunately, generic drivers are available from a variety of sources.

Drivers from device manufacturers include the Microchip General-Purpose USB Windows Driver, Cypress Semiconductor's CY4604 USB Developer's uStudio, and the Silicon Labs USBXpress host library. FTDI Chip offers the D2XX Direct Driver, which applications can use to access FTDI Chip's controllers using vendor-specific

USB IN BRIEF

Here are some essential facts for anyone who is designing a device that uses a USB port.

HOSTS AND DEVICES

Every USB communication is between a host and a device. A USB host is a PC or another computer that contains USB host-controller hardware and software. The host controls communications on the bus. A USB device contains USB device-controller hardware and program code, often called device firmware. The device responds to communications from the host.

On power-up or device attachment, the host computer requests information from the device in a process called enumeration. The device sends a series of data structures called descriptors, which tell the host about the device and its capabilities.

A Windows host compares the contents of the descriptors with the information in the PC's INF files. The file with the best match tells the host what class driver or device driver to assign to the device. (Other operating systems use similar methods to select a driver.) The driver is software that manages communications between applications and the lower-level drivers that access the USB hardware.

Windows includes drivers for popular device classes, including human-interface devices (mice, keyboards, game controllers), mass storage (drives), audio and video devices, printers, cameras, and more.

DEVICE CONTROLLERS

The device controller is hardware that can be embedded in a microcontroller chip or in a separate chip that interfaces to a microcontroller or other CPU. Microcontrollers with embedded USB controllers are available from many sources, including Microchip Technology, Atmel Corporation, Silicon Laboratories, and Cypress Semiconductor. Chips that interface to a microcontroller or CPU are available from Philips Semiconductors, National Semiconductor, and others.

Every USB device must have the intelligence to understand and respond to received requests and other events on the bus. Controller chips vary in how much firmware support they require for handling the low-level USB protocols. Most chip vendors provide example firmware that you can adapt for a specific application.

TRANSFERRING DATA

For every communication, the host specifies an endpoint address in the device. The endpoint address is typically a buffer or register that holds received data or data waiting to transmit.

USB supports three bus speeds. Low speed can guarantee bandwidth of only 800 bytes/sec per endpoint address but is useful for some inexpensive devices such as keyboards and mice. Full speed can transfer data to or from an endpoint address at up to 1.2 Megabytes/sec. For devices that need more speed, a high-speed endpoint can transfer data at over 30 Megabytes/sec.

USB uses four transfer types (Table 1). Typical uses for each type include enumeration for control transfers, printer and scanner data for bulk transfers, mouse and keyboard data for interrupt transfers, and real-time audio and video for isochronous transfers.

TRANSFER TYPE	CONTROL	BULK	INTERRUPT	ISOCHRONOUS
REQUIRED BY ALL DEVICES	yes	no	no	no
ALLOWED AT LOW SPEED	yes	no	yes	no
SUPPORTS ERROR CHECKING	yes	yes	yes	no
GUARANTEED TRANSFER RATE	no	no	no	yes
GUARANTEED MAXIMUM TIME BETWEEN TRANSFER ATTEMPTS	no	no	yes	yes

TABLE 1. USB's four transfer types provide options to fit the needs of any device.

functions instead of COM-port programming. Some development boards come with drivers that you can use to access the controller on the board. Other drivers, such as Tetradyne Software, Inc.'s DriverX USB, are for use with any controller chip.

If you're switching to Windows Vista, you can use the operating system's WinUSB driver. The driver provides functions for accessing any device that doesn't use Windows class drivers or isochronous transfers.

The Vendor ID Dilemma

Every USB device must contain a Vendor ID and Product ID (Listing 2). The host requests these 16-bit values from the device during enumeration and uses the values to help in selecting a driver for the device.

The owner of the Vendor ID assigns a Product ID to each product released by the vendor. Every device with the same Vendor ID/Product ID pair should communicate in the same way with the PC. If two devices with different communication requirements contain the same Vendor ID/Product ID pair, one or both devices are likely to fail to perform as intended.

The rights to use a Vendor ID cost $1,500 from the USB Implementers Forum (**usb.org**). If you don't have a Vendor ID and your budget doesn't allow obtaining one, several options are available.

Users of FTDI Chip's controllers can use the Vendor ID and Product ID programmed into each controller. Because the controllers handle the USB communications entirely in hardware, the controllers appear identical to the host computer. The controllers may connect to circuits that perform different functions, but the host PC doesn't have to know or care about anything that happens beyond the USB interface.

Some chip manufacturers provide free blocks of Product IDs for customers. You can use the manufacturer's Vendor ID and the provided Product IDs in products that you develop using the manufacturer's controllers. Microchip is one manufacturer that offers Product IDs. FTDI Chip also has this option for those who want a unique Product ID.

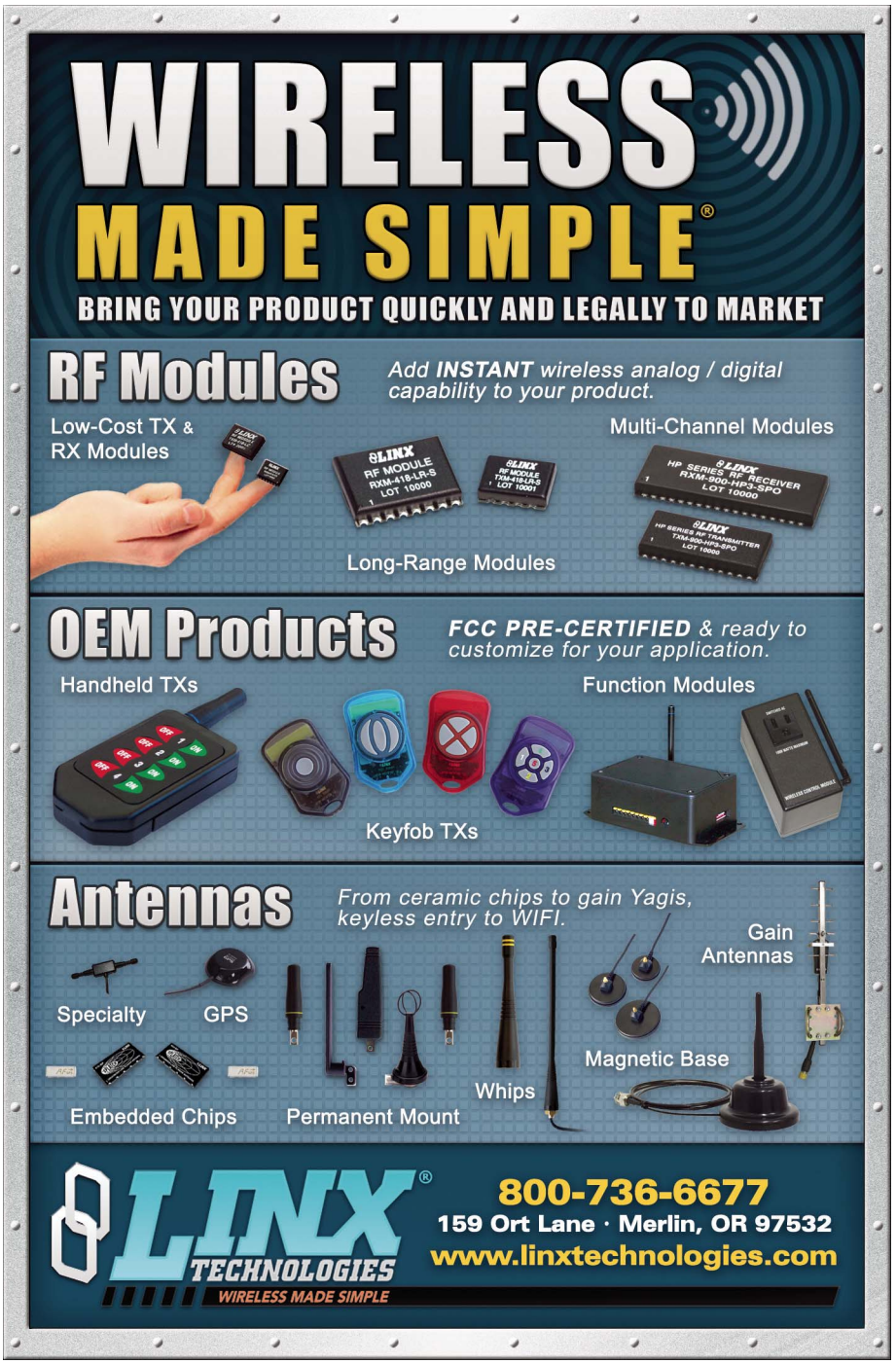
Some development boards that come with a driver have a Vendor ID and Product ID that you can use in products that use the driver.

Learning More

For many projects, one of the approaches described here can provide a way to add USB to a device with minimal expense and hassle. For more about USB developing, including links to the products mentioned in this article plus free example device firmware and host software, visit my USB pages at **www.Lvr.com**. **NV**

AUTHOR BIO

Jan Axelson is author of the books *USB Complete* and *USB Mass Storage.*



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IN THE SPOTLIGHT

An Interview with Wayne Thorpe: President and CEO of Circuit Specialists, Inc.

by Marvin Mallon

Mesa, AZ is home to one of the largest distributors of electronic equipment and supplies in the country. The 12,000 square foot facility of Circuit Specialists, Inc., houses the more than 11,000 items that they sell by mail order, as well as online. Fourteen employees oversee the operation of this company that has been in business since 1971.

This privately-owned corporation was founded by two brothers — Leon and Darrel Thorpe. Darrel worked for Motorola in Scottsdale, AZ and thought that those wonderful new devices called integrated circuits would be a good product to sell via mail order. Leon made a financial investment and they both started Circuit Specialists. They kept their regular jobs and met in the evenings to prepare the orders and ship them out.

Darrell sold his interest in the company back in 1984 and still resides in Scottsdale. Leon stayed active until 1998 when his health began to deteriorate. He passed away this past September.

In 1984, Leon's son, Wayne, joined the operation. He assumed the role of President and CEO at that time. When interviewed for this column, Wayne Thorpe replied to the following questions:

Marvin: Where were you employed prior to coming on-board at Circuit Specialists?
Wayne: I worked in the electronics industry as a professional sales representative for GC Electronics. I covered the Southwest territory of Arizona, New Mexico, and West Texas from 1977 till 1979. In 1980, I joined the Heath Group of Phoenix as Vice President. They are a sales marketing company that I worked with over the next four years.

M: Where and when were you born?
W: I was born in 1950 in Stretford, England, a suburb of Manchester. Dad was in the US Air Force and married while stationed there. We lived off base and I attended local schools for most of the time. I ended up thinking I was British. When I was 16 years old my parents and I moved to the US.

M: Any hobbies or interests other than overseeing the operation of your family-owned business?
W: I played football (that's what the British call soccer) as a kid in England. To this day, I help to organize and coach a high-level soccer team and serve as an off-campus advisor at a Phoenix-area high school.

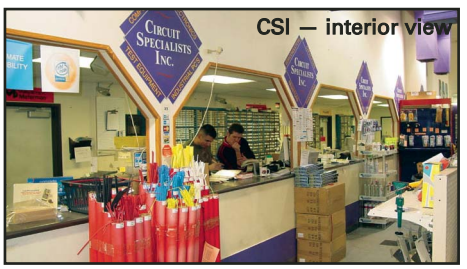
M: Getting back to business, tell us more about Circuit Specialists.
W: Since the mid 1980s, we have focused on importing products from Taiwan, Korea, and China so that we can offer our customers excellent value. We maintain an agency office in Taipei and we have a full time employee and office in ShenZhen, China to help us facilitate sourcing of products. This strategy allows us to cut out the profit from the traditional importer, which makes us more competitive without degrading the quality of the products we can offer. We are strongest in test equipment, power supplies, soldering equipment, and PC-based data acquisition and control products and tools. Additionally, we maintain stock on some major brand name products such as FLUKE. We also have a large inventory of old style DIP ICs, as well as LEDs, diodes, capacitors, and other passive components.

220 S. Country Club Dr., Mesa, AZ 85210
Tel: **800-528-1417**
Web: **www.CircuitSpecialists.com**.

M: Is there a newly developed product ready for release?
W: We are currently incubating a new CNC (Computer Numerical Control) department. We have set up a machining shop in-house to develop prototypes of various standard CNC systems that we will offer. We have already sourced our primary raw stock and electronics from Taiwan and China and we feel we can penetrate this sector of the market by offering very good quality CNC platforms at industry best price points.

M: Finally, is there anything else you care to say about your organization?
W: Circuit Specialists has been providing electronic equipment and supplies to educational institutions, corporate entities, and government/military customers for over 35 years. We ship most items from stock the same day we receive the order. Additionally, our website shows our current stock levels to our customers so they can make an appropriate decision based on their requirements for delivery. When an order is shipped, our customers get an auto-generated email providing them with a packing list and a UPS tracking number.

Our most important customer is the individual hobbyist, designer, or small manufacturer. We strive to offer best value deals on quality products. Our goal is to provide great customer service and our strategy is to offer good products at great prices. **NV**



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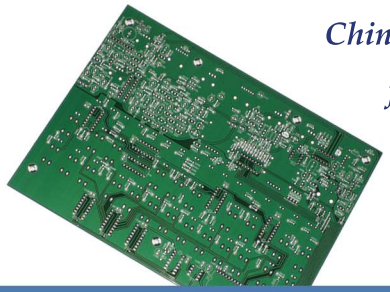

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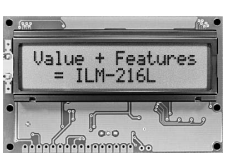

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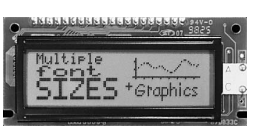

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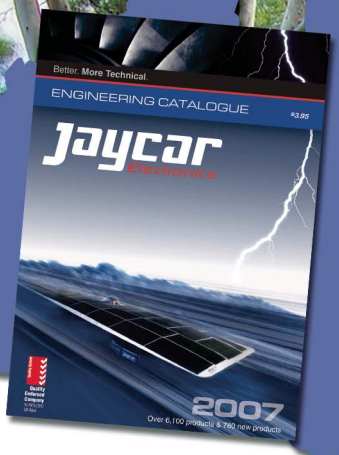

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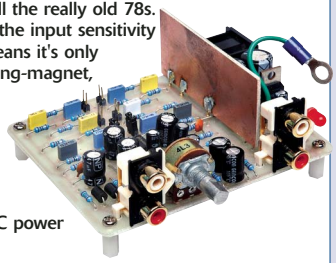
- Requires 12VAC power



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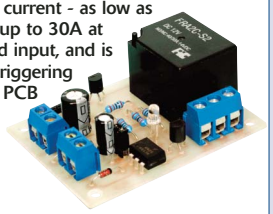

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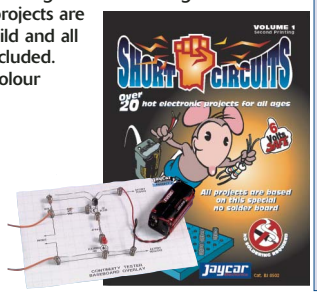

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- Optional coil driver
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- Kit supplied with PCB, and all electronic components.

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Knock Sensor

KC-5444 $10.00 + post & packing

Add this option to your KC-5442 Programmable High Energy Ignition system and the unit will automatically retard the ignition timing if knocking is detected. Ideal for high performance cars running high octane fuel. Requires a knock sensor interface which is cheaply available from most auto recyclers.

- Kit supplied with PCB, and all electronic components.

Car Air Conditioner Controller Kit

KC-5437 $23.25 + post & packing

This kits stops the air conditioner in your car from taking engine power under acceleration. It will allow the compressor to run with low throttle even when the cabin temperature setting has been reached and will automatically switch the compressor off at idle. It also features an override switch, an LED function indicator. Kit supplied with PCB with overlay and all electronic components with clear English instructions.

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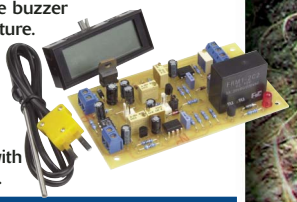

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FUSE AND METER SAVERS

by Bill Stiles

Don't Blow Fuses or Your Meter

Here are three circuits which can save time and prevent frustration. They go well with "Don't Blow a Fuse" by Ronald Newton (*Nuts & Volts*, August 2006, page 40). When I built his circuit breaker box, I added two test leads with insulated alligator clips for fuses in a fuse post holder.

My first circuit — shown in Figure 1 — is connected in the AC input of the equipment being tested, with S1 set to "lamp." Blown fuses in the equipment are bridged with Mr. Newton's substitution box (or replaced). If Lmp1 and Lmp2 are correctly chosen, new fuses will not blow, even with shorts in the power supply of the equipment.

If the lamp or lamps light brightly, there is probably a short. The lamps are dependent on the power used by the equipment. The two lamps shown (40 Watt and 60 Watt in parallel) are suitable for equipment drawing 50 to 70W. For smaller power use, one of the lamps can be unscrewed.

I also use a 200W lamp and a 25W lamp, for large and small power usage. If the lamp(s) light only dimly — if at all — full voltage can be applied to the equipment by switching S1 to "direct." The "off" position of S1 is used to completely remove power from the equipment while you are working on it. I used a double-pole switch because I have seen several cases where the neutral and hot wires are reversed.

SO2 is added for very large loads. Several years ago, I had a 1/4 horsepower motor with burned insulation in the start switch. It would blow a fuse as soon as it was turned on. I plugged a 1,000W electric heater into SO2, which prevented the fuse from blowing and allowed me to see arcing at the burned insulation inside the switch. Fortunately, the switch was mounted on the outside of the motor, where it could be easily replaced.

I also use this circuit to check for shorted turns in a power transformer. Disconnect the output of the transformer, and use only one 40W or 25W lamp. A large transformer may light the lamp dimly from internal losses; smaller transformers should not light the lamp at all.

Measuring the Fuse Current

As Mr. Newton mentioned, it is desirable to connect an amp meter in series with the fuse substitution box. A single meter could be used but a multi-meter with several current ranges is better. However, there may be a problem at higher currents.

Many digital multimeters have a 10 or 20 amp range, but the duty cycle is limited to something like "30 seconds on and 15 minutes off." With Figure 2, a DMM can be used for high current with no time limits.

Set the meter to measure AC or DC voltage, as appropriate. Connect PL2 to one of the banana jacks on the fuse substitution box, and one of the leads from the fuse adapter to J3. For current of 10A, the meter will read 1.0 volts; for 1A, the reading will be 0.1 volts (100 millivolts).

Figure 3 is a circuit similar to Figure 2, which provides an easy way to connect a DMM to measure the AC input current.

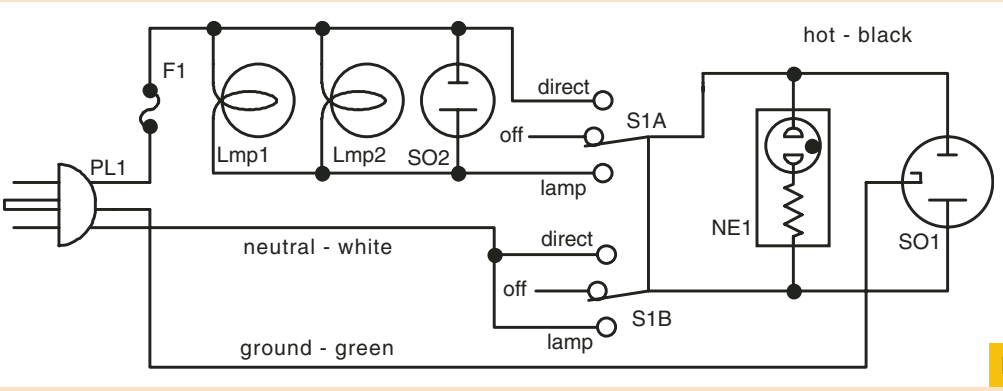


FIGURE 1. A Current Limiter.

(For nearly all electronic equipment, the power line current is not a sine wave, and a true RMS meter must be used for accurate current measurement.) S2 (optional), when used with an auto-ranging DMM, allows a quick check of both voltage and current.

Construction

Each circuit was built in a plastic project box. A rather large box is required for Figure 1. F1 is chosen for the current rating of S1, PL1, and SO1, but not larger than 15A when R1 is rated at 40W. I used two 0.2 Ohm, 20W resistors in parallel for R1. Sockets for Lmp1 and Lmp2 are surface mount sockets for standard incandescent lamps, available from most larger electric supply stores. The sockets I used have exposed terminals; I mounted them inside the project box, with holes in the box cover to allow the lamps to be inserted into the sockets. I used a switch rated at 10 amps, 250 volts for S1. S2 can have a low current rating, but be sure it is rated for the power line voltage. **NV**

FIGURE 2. Current Adapter for Meter.

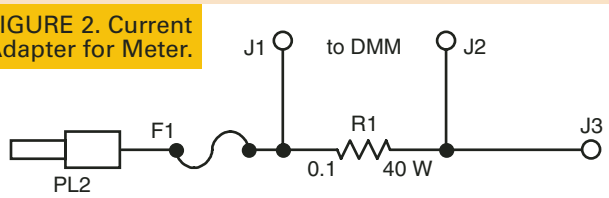
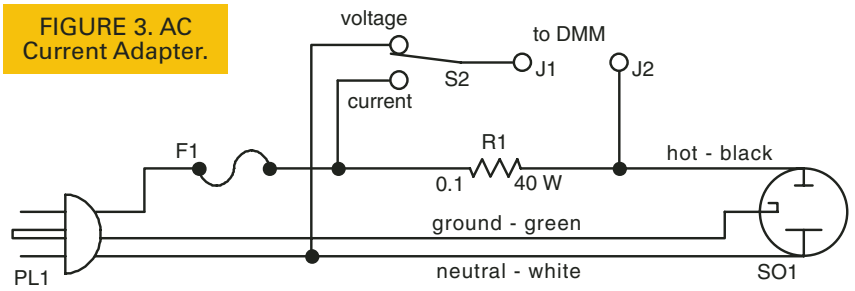


FIGURE 3. AC Current Adapter.



PARTS LIST

ITEM	DESCRIPTION
• PL1	Grounding AC cord and plug
• PL2	Banana plug and wire
• SO1	Grounding AC socket
• SO2	Two terminal AC socket
• F1	Circuit breaker or fuse
• Lmp1	40 watt incandescent lamp (see text)
• Lmp2	60 watt incandescent lamp (see text)
• S1	DPDT center-off toggle switch
• S2	SPDT toggle switch (optional)
• NE1	Neon pilot lamp
• R1	0.1 ohm, 40 watt resistor (see text)
• J1, J2	Tip jacks to accept DMM probes
• J3	Banana jack

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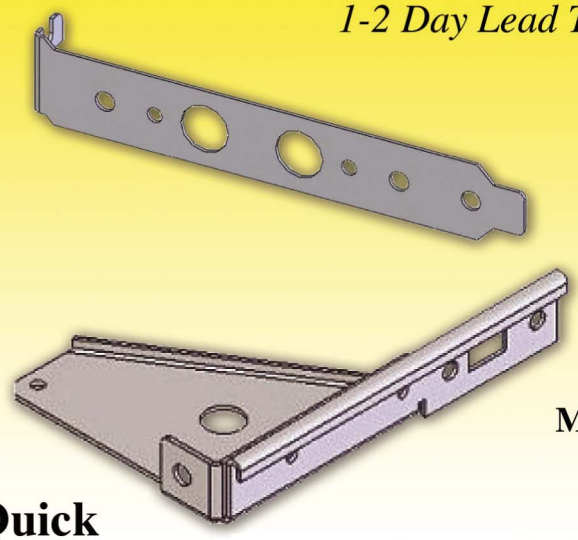

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Understanding Digital Buffer, Gate, and Logic IC Circuits

by Ray Marston

PART 1: Digital Buffer IC Circuits

Ray Marston explains logic gate basics and takes a detailed look at practical TTL and CMOS digital buffer IC circuits in this opening installment of a five-part mini series.

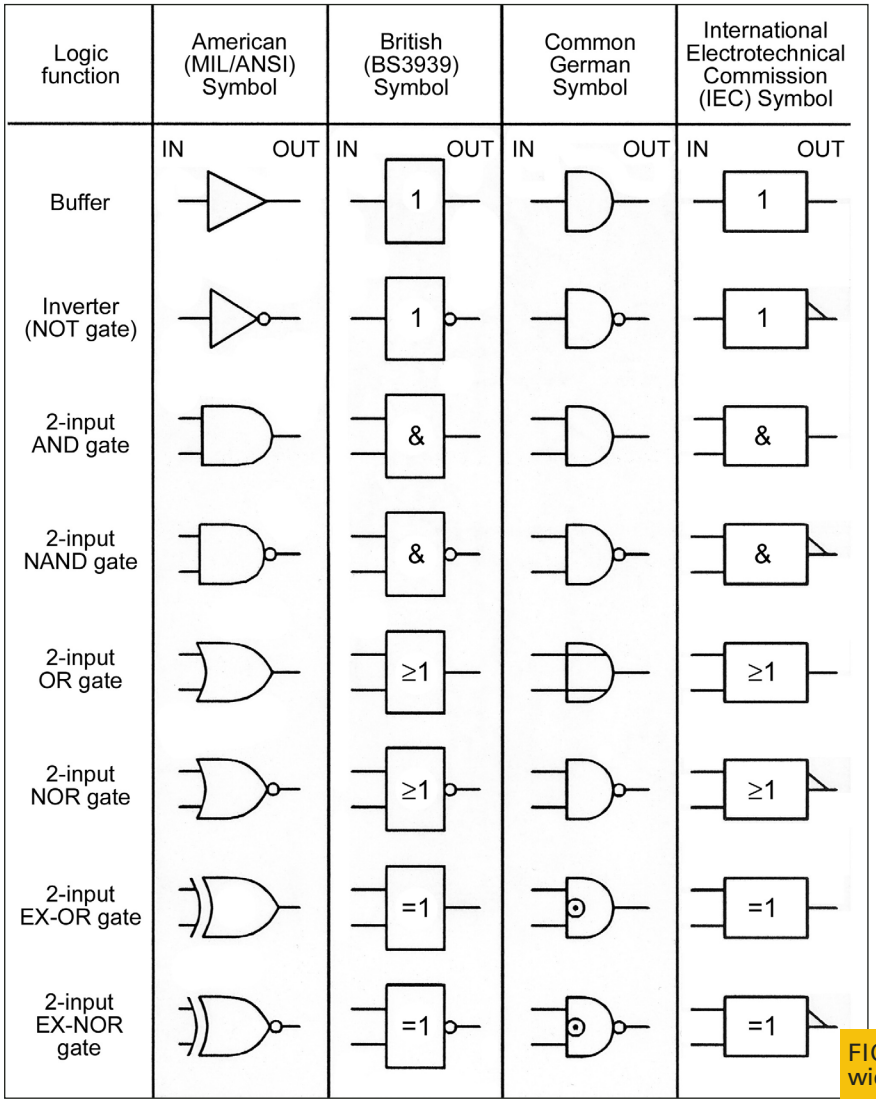


FIGURE 1. A selection of widely used logic symbols.

Logic Gate Symbology

The eight best known types of digital logic gates are the buffer and the NOT, OR, NOR, AND, NAND, XOR (EX-OR), and XNOR (EX-NOR) types. Many different symbols can be used to represent each of these eight basic logic gate elements. Figure 1 shows four different families of symbols that are widely used in different parts of the world today; of these, the American MIL/ANSI symbols are by far the most popular, are instantly recognizable, are used by most of the world's practical digital engineers, and are used throughout this series.

Two useful variations of these American symbols are also widely used and are shown added to a standard inverter symbol in Figure 2; the left-hand symbol is internationally recognized and indicates that the logic element has a Schmitt trigger input action; the right-hand symbol — which is widely used but is not universally recognized — indicates that the logic element has an open-drain (o.d.) or open-collector (o.c.) output stage.

Logic Gate Functions

The functional action of any logic gate can be described either in words or in a tabular or symbolic way. The following list describes the functions of all eight basic types of logic

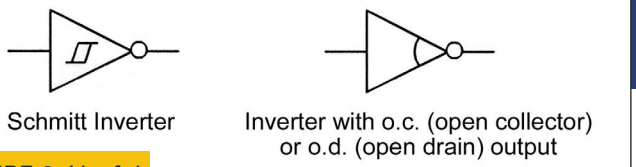


FIGURE 2. Useful variations of the MIL/ANSI inverter symbol.

gates in words.

• *Buffers* — A buffer is a non-inverting amplifier that has an output drive capacity that is far greater than its input drive requirement, i.e., it has a high fan-out and gives a logic 1 output for a logic 1 input, etc.

• *Inverters* — An inverter (also known as a NOT gate) is a high fan-out amplifier that gives a logic 1 output for a logic 0 input, and vice versa.

• *AND Gates* — An AND gate has an output that is normally at logic 0 and only goes to logic 1 when *all* inputs are at logic 1, i.e., when inputs A and B and C, etc., are high.

• *NAND Gates* — A NAND gate is an AND gate with a negated (inverted) output; the output is normally at logic 1 and only goes to logic 0 when *all* inputs are at logic 1.

• *OR Gates* — An OR gate has an output that goes to logic 1 if *any* input is at logic 1, i.e., if inputs A or B or C, etc., are high. The output goes to logic 0 only if *all* inputs are at logic 0.

• *NOR Gates* — A NOR gate is an OR gate with a negated output; it has an output that goes to logic 0 if any input is at logic 1, and goes to logic 1 only when all inputs are at logic 0.

• *XOR Gates* — An exclusive-OR (EX-OR) gate has two inputs, and its output goes to logic 1 only if a *single* input (A or B) is at logic 1; the output goes to logic 0 if *both* inputs are in the same logic state.

• *XNOR Gates* — An exclusive-NOR (EX-NOR) gate is an EX-OR gate with a negated output, which goes to logic 1 if *both* inputs are in the same logic state, and goes to logic 0 only if a single input is at logic 1.

Figure 3 shows how the functions of the eight basic types of gates can also be presented in tabular form via truth tables (which show the logic state of the output at all possible input logic state combinations) or symbolically via Boolean algebraic terms. Note that, by convention, all logic gate inputs are notated alphabetically as A, B, C, etc., and the output terminal is notated as Y (in counters and flip-flops, etc., the main output is usually notated as Q). The actual logic states may be represented by 0 and 1, as shown, or by L (= Low logic level) and H (= High logic level). Also note in the Boolean expressions that a negated output is indicated by a negation bar drawn above the basic

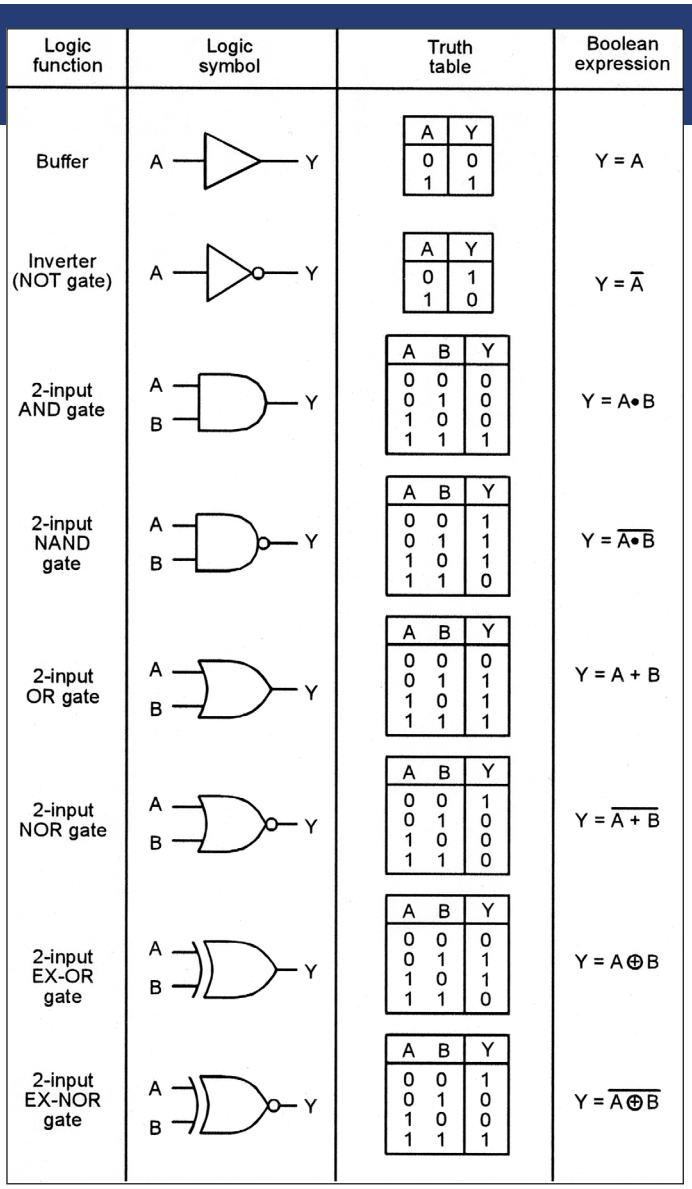


FIGURE 3. Symbols, truth tables, and Boolean expressions for the eight basic types of logic gates.

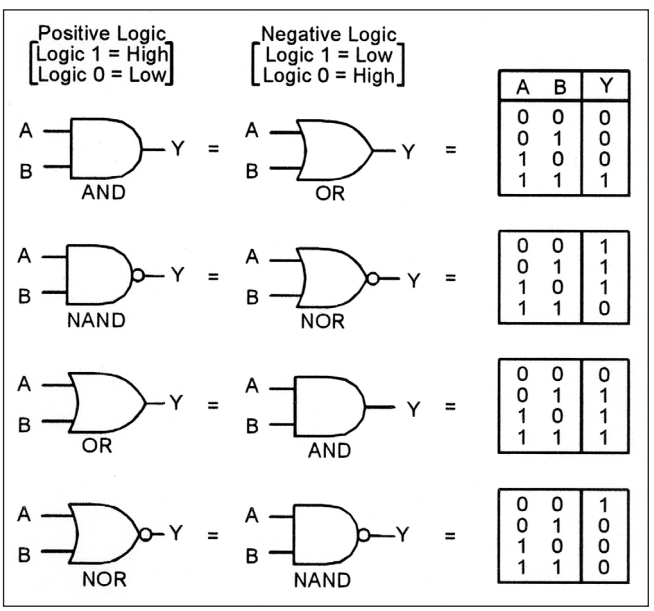
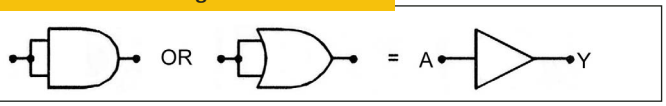


FIGURE 4. Basic sets of two-input positive and negative logic equivalents.

FIGURE 5. Any AND or OR gate can be used as a non-inverting buffer element.



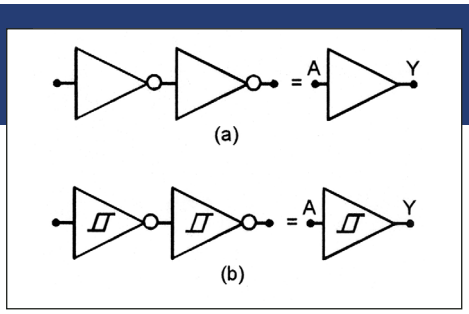
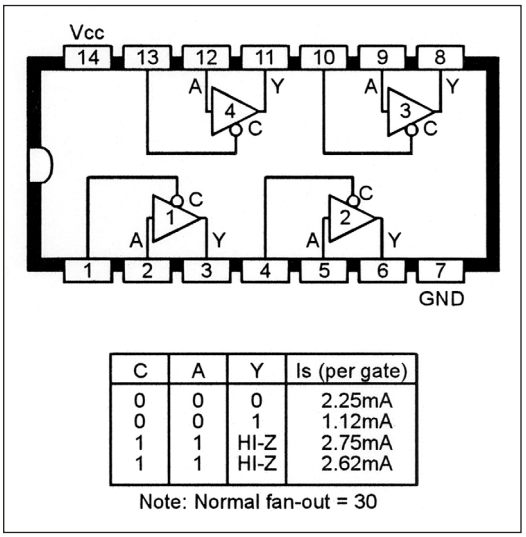


FIGURE 6. Any two elements from an inverter IC can be used to make a non-inverting buffer element.

Device	Type	Description
74LS125	LS TTL	QUAD 3-state buffer
4050	CMOS	Hex buffer
4503B	CMOS	Hex (Dual Quad) 3-state buffer
7407	TTL	Hex buffer with 30V o.c. outputs
74LS365	LS TTL	Hex 3-state buffer
74HC4050	CMOS	Hex buffer
74HC241	CMOS	Octal (Dual Quad) 3-state Schmitt buffer
74HC244	CMOS	Octal (Dual Quad) 3-state Schmitt buffer
74LS244	LS TTL	Octal (dual Quad) 3-state Schmitt buffer

FIGURE 7. Nine popular non-inverting buffer ICs.



C	A	Y	Is (per gate)
0	0	0	2.25mA
0	0	1	1.12mA
1	1	HI-Z	2.75mA
1	1	HI-Z	2.62mA

Note: Normal fan-out = 30

FIGURE 8. Functional diagram and truth table, etc., of the 74LS125 Quad three-state buffer/bus-driver IC.

output symbol; the negated state is called a not state; thus, a negated Y output is called a not-Y output.

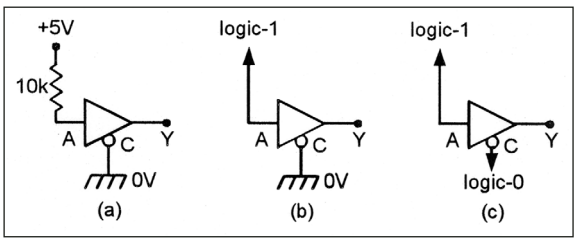


FIGURE 9. All unwanted 74LS125 elements must be connected in one of these ways.

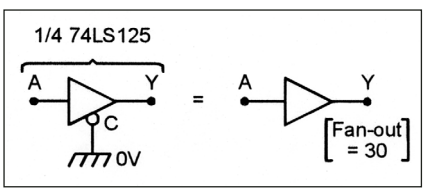


FIGURE 10. Methods of using a 74LS125 element as a normal buffer.

Positive Versus Negative Logic

All modern digital logic circuitry assumes the use of the positive logic convention, in which a logic 1 state is high and a logic 0 state is low. In the early days of electronic digital circuitry, an alternative 'negative logic' convention — in which a logic 1 state is low and a logic 0 state is high — was also in common use, and it is sometimes still useful to be able to think in negative-logic terms, particularly when designing gates in which a low state output is of special interest. With this point in mind, Figure 4 presents a basic set of two-input positive and negative logic equivalents. Thus, it can be seen that a negative logic AND gate action — in which the output is low only when both inputs are low — is directly available from a positive logic OR gate, and so on.

Practical Buffer IC Circuits

Digital buffer ICs have two main purposes: to act either as simple non-inverting, current-boosting interfaces between one part of a circuit and another, or to act as three-state switching units that can be used to connect a circuit's outputs to a load, only when required. If you ever need only a few simple buffers, one cheap way to get them is to make them from spare AND or OR elements (as shown in Figure 5) or from pairs of normal or Schmitt inverters (as shown in Figure 6).

Figure 7 lists basic details of nine popular, non-inverting digital buffer ICs. When using these ICs, note that all unused buffers must be disabled by tying their inputs to one of the IC's supply lines. In CMOS devices, the unused inputs can be tied directly to either supply line, but in TTL devices, it is best (for lowest quiescent current consumption) to tie all unused inputs high via a common 10K resistor. If the unused buffer is a three-state type, it should (if it has independent control) be set into

FIGURE 11. Methods of using a 74LS125 element as a three-state line-driving buffer.

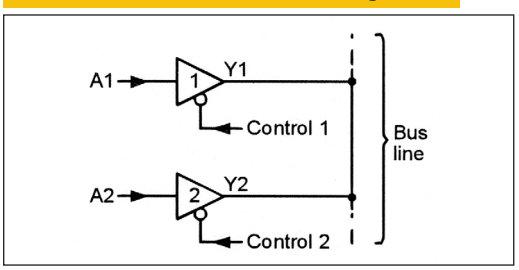
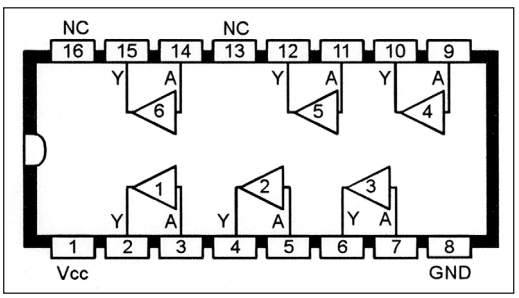
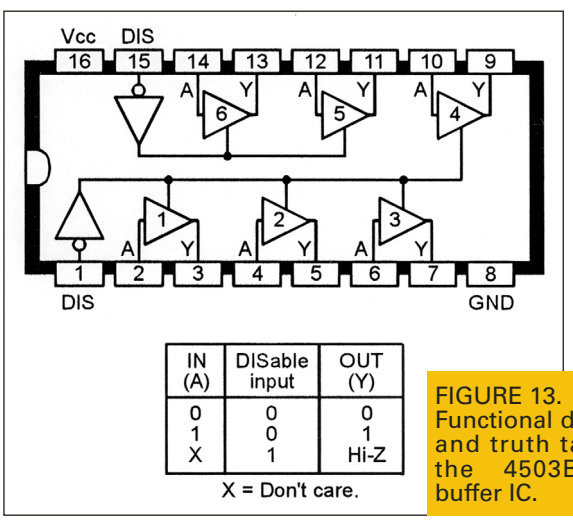


FIGURE 12. Functional diagram of the 4050B or 74HC4050 Hex buffer IC.





IN (A)	DISable input	OUT (Y)
0	0	0
1	0	1
X	1	Hi-Z

X = Don't care.

FIGURE 13. Functional diagram and truth table of the 4503B Hex buffer IC.

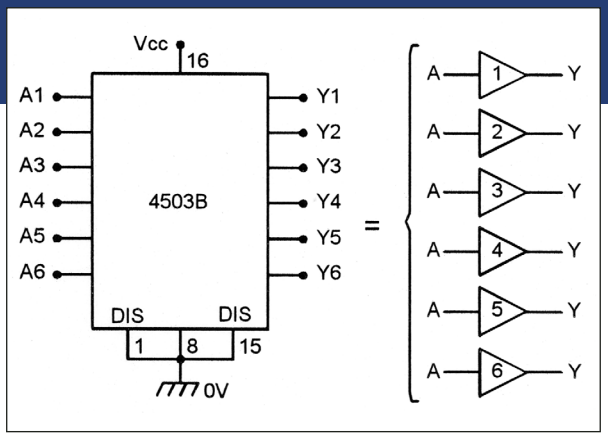


FIGURE 14. Method of connecting the 4503B for use as six normal buffers.

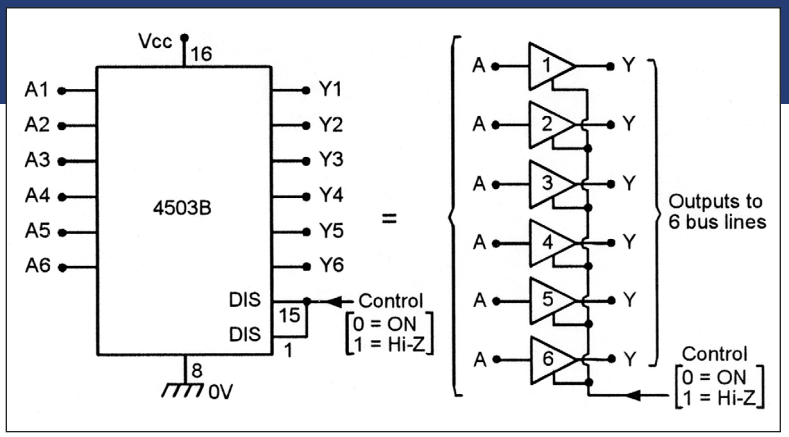


FIGURE 15. Method of connecting the 4503B for use as a three-state Hex buffer controlled via a single input.

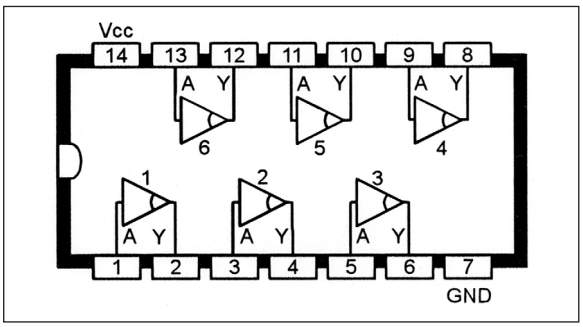


FIGURE 16. Functional diagram of the 7407 Hex buffer with 30V o.c. outputs.

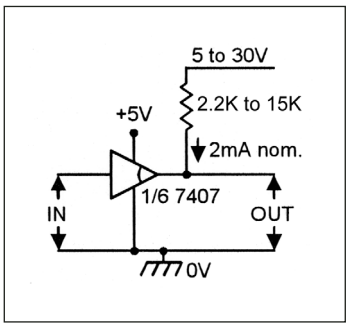


FIGURE 17. A 5V to high-voltage buffer/interface.

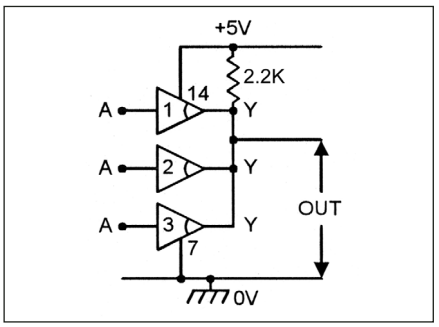
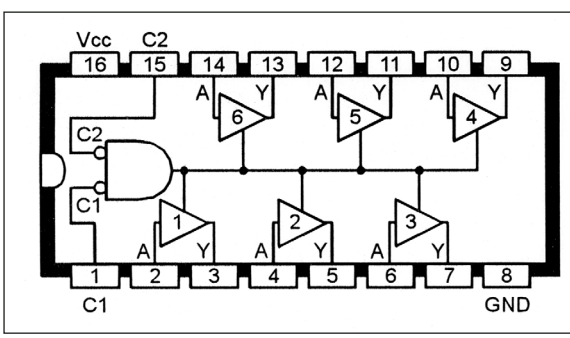


FIGURE 18. Three 7407 buffers used to make a three-input wired AND gate.

its normal mode via its control input.

Dealing now with the individual buffer ICs listed in Figure 7, Figure 8 shows the functional diagram and truth table, etc., of the 74LS125 TTL IC, which houses four independently controlled, three-state buffers and is so modestly priced that it is still worth using, even if you do not need the three-state facility. Note from the truth table that each of the four elements acts as a normal buffer when its control terminal (C) is in the logic 0 state, and that the element's quiescent current (I_s) is least when C is at logic 0 and the buffer's input (A) is at logic 1.

Thus, any unwanted elements should be disabled by tying their C terminals low and their A terminals high, using one of the methods shown in Figure 9. Any element can be used



C1	C2	A	Y
1	X	X	HI-Z
X	1	X	HI-Z
0	0	1	1
0	0	0	0

Notes: X = either 0 or 1 logic levels.
Fan-out = 30 per gate.

FIGURE 19. Functional diagram and truth table of the 74LS365 Hex three-state buffer.

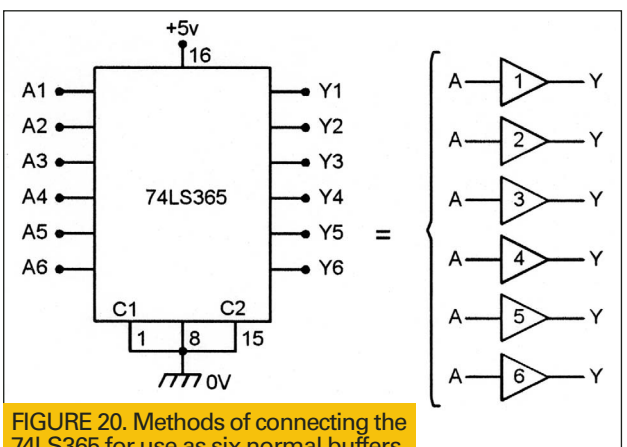


FIGURE 20. Methods of connecting the 74LS365 for use as six normal buffers.

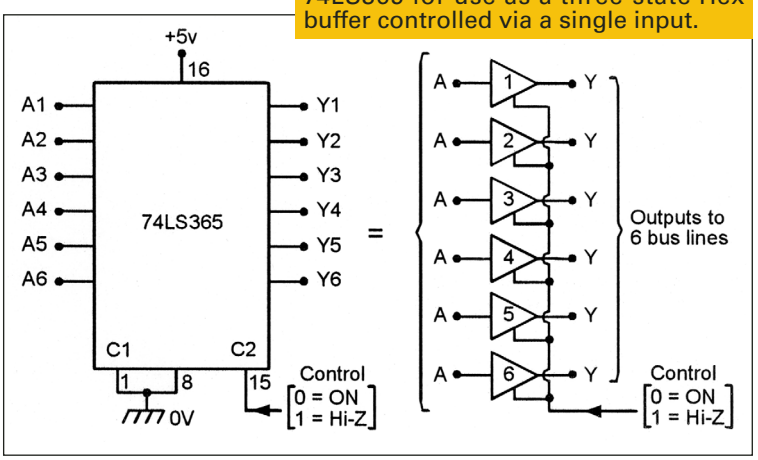
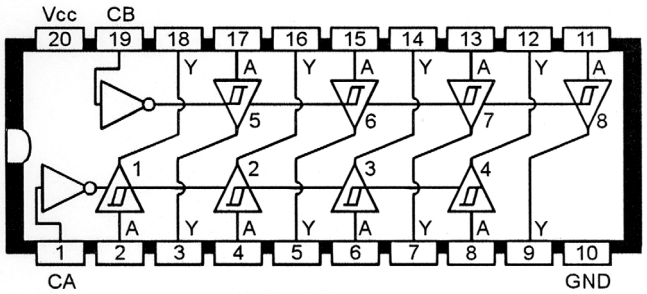


FIGURE 21. Methods of connecting the 74LS365 for use as a three-state Hex buffer controlled via a single input.



'C'	A	Y
0	0	0
0	1	1
1	0	HI-Z
1	1	HI-Z

FIGURE 22. Functional diagram and truth table of the 74LS244 (or 74HC244) Octal (dual Quad) three-state Schmitt buffer IC.

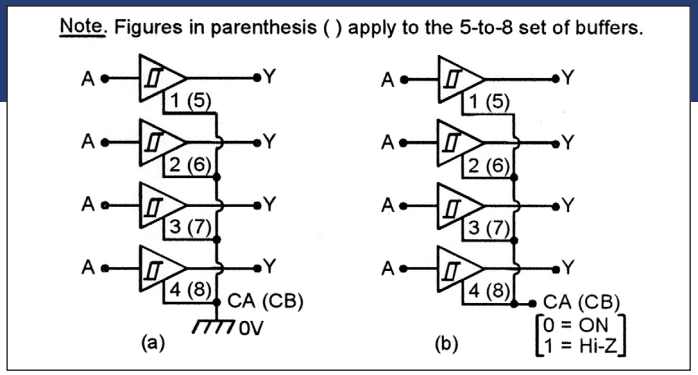


FIGURE 23. The 74LS244 Quad buffers can be used as (a) simple Schmitt buffers, or as (b) three-state ganged Schmitt buffers.

as a normal buffer by grounding its C terminal (Figure 10), or as a three-state buffer that drives a common bus line by using it as shown in Figure 11.

If you need up to six simple CMOS buffers, one of the cheapest ways to get them is via a 4050B or 74HC4050 Hex buffer IC. Figure 12 shows the IC's functional diagram; each buffer can source up to 10 mA or sink up to 40 mA of output current when the IC is powered from a 15V supply.

If you need up to six three-state CMOS buffers, one option is to use a 4503B Hex buffer IC. Figure 13 shows the functional diagram and truth table of this versatile IC, in which pin 1 acts as a DISABLE input that controls four of the six buffers, and pin 15 acts as a DISABLE input that controls the other two buffers. Note that each buffer element acts as a normal buffer when its DISABLE pin is at logic 0 (low), and goes into the high-impedance output state when its DISABLE pin is at logic 1 (high).

Thus, this IC can be used as a simple Hex buffer by wiring it as shown in Figure 14 (with pins 1 and 15 grounded), or as a Hex three-state buffer that is controlled via a single input by wiring it as shown in Figure 15 (with pins 1 and 15 shorted together and used as a DISABLE input).

Figure 16 shows the functional diagram of the 7407, which is a standard TTL Hex buffer in which each buffer has an open-collector output that can sink up to 40 mA and can be connected to a supply of up to 30V via an external current-limiting pull-up resistor (but the actual IC must use a 5V supply). Figure 17 shows how one of these buffers can be used as a 5V to high-voltage (up to 30V) non-inverting interface. Figure 18 shows how three o.c. buffers can be made to act as a wired AND gate by wiring all three outputs to the same pull-up resistor. The circuit action is such that the output is pulled low when any input is low, and only goes high when all three inputs are high, thus giving an AND action.

Figure 19 shows the functional diagram and basic truth table of a 74LS365 Hex three-state buffer IC, in which all six buffers share a common AND-gated control line. This IC can be used as six normal buffers by grounding its two control pins as shown in Figure 20, or as a set of six three-state buffers that are all switched via one common control signal as shown in Figure 21; AND-type three-state control can be obtained by using both Control terminals (pins 1 and 15).

Finally, the 74HC241, 74HC244, and 74LS244 are 'Octal' three-state Schmitt buffers in which the buffers are split into two groups of four, with the mode of each group controlled via a separate input. Figure 22 shows the functional diagram and truth table of the 74LS244 IC (the 74HC244 is similar, but it has Schmitt-type CA and CB inputs).

The IC is really a dual Quad device, in which buffers 1-4 are controlled via the CA terminal, and buffers 5-8 are controlled via the CB terminals. Each of these Quads can be used as a set of simple Schmitt buffers by grounding its control terminal as shown in Figure 23(a), or as a ganged set of three-state Schmitt buffers by using its control terminal as shown in Figure 23(b). **NV**

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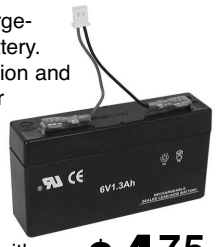

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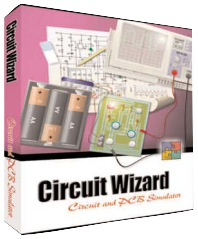

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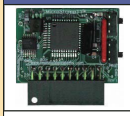

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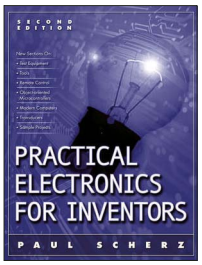
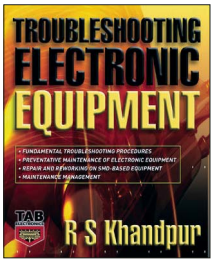
ELECTRONICS

Practical Electronics for Inventors
by Paul Scherz



This intuitive, applications-driven guide to electronics for hobbyists, engineers, and students doesn't overload readers with technical detail. Instead, it tells you — and shows you — what basic and advanced electronics parts and components do, and how they work. Chock-full of illustrations, *Practical Electronics for Inventors* offers over 750 hand-drawn images that provide clear, detailed instructions that can help turn theoretical ideas into real-life inventions and gadgets. **$39.95**

Troubleshooting Electronic Equipment
by R. S. Khandpur



From cell phones to medical instruments to digital and microprocessor based equipment, this hands-on, heavily illustrated guide clearly explains how to troubleshoot, maintain, and repair all types of electrical equipment. The author covers all the essentials such as necessary tools, soldering techniques, testing, fundamental procedures, and mechanical and electrical components. **$49.95**

Nuts & Volts of BASIC Stamps — Volume 7
by Jon Williams

Nuts & Volts of BASIC Stamps, Volume 7 includes articles #129-140 from *Nuts & Volts Magazine*. In this 2006 collection, BASIC Stamp 1, BASIC Stamp 2, SX/B, and Propeller programming are explored in a series of real-world applications. This book is useful for the *Nuts & Volts* reader, newcomers to BASIC Stamp, SX, and Propeller microcontroller projects, and seasoned programmers looking for new ideas. **$14.95**

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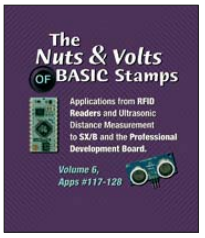
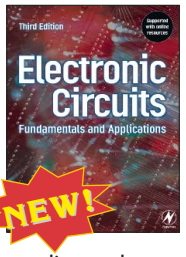
Nuts & Volts of BASIC Stamps — Volume #6
by Jon Williams



Nuts & Volts of BASIC Stamps — Volume 6 includes articles #117-128, written for 2005. Article topics consist of RFID Readers and Ultrasonic Measurement, SX/B and the Professional Development Board, the advanced MIDI receiver, programming the SX microcontroller in BASIC, mastering the MC14489 display driver, and more! The Nuts & Volts of BASIC Stamps books are a favorite Parallax technical pick and are a tremendous technical resource for all PBASIC programming projects. **$14.95**

Electronic Circuits — Fundamentals & Applications: Third Edition
by Mike Tooley



In *Electronic Circuits*, Mike Tooley provides all the essential information required to get to grips with the fundamentals of electronics, detailing the underpinning knowledge necessary to appreciate the operation of a wide range of electronic circuits, including amplifiers, logic circuits, power supplies, and oscillators. The third edition now offers an even more extensive range of topics, with extended coverage of practical areas such as circuit construction and fault finding, and new topics including circuit simulation, electronic CAD, and a brand new chapter devoted to the PIC microcontroller. **$34.95**

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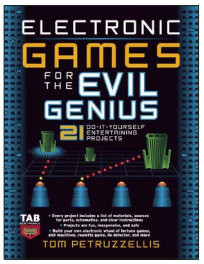
by Thomas Petruzzellis



You can have a wicked amount of fun on your way to becoming a game master! In *Electronic Games for the Evil Genius*, popular how-to author Tom Petruzzellis gives you everything you need to build 35 exciting games and gadgets. You get complete, easy-to-follow plans, with clear diagrams and schematics, so you know exactly what's involved before you begin. Packed with fun projects that you'll love to build and play with, this guide develops game expertise one simple step and project at a time. **$24.95**

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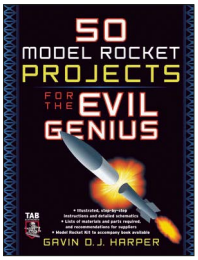
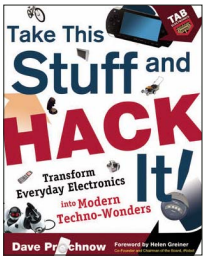
by Gavin D J Harper



The fun, hands-on way to learn about rocket science. Yes, as a matter of fact, is IS rocket science! And because this book is written for the popular Evil Genius format, it means you can learn about this fascinating and growing hobby while having fun creating 50 great projects. You will find a detailed list of materials, sources for parts, schematics, and lots of clear, well-illustrated instructions. **$24.95**

Take This Stuff and Hack It!
by Dave Prochnow



Transform common household items into really cool stuff. You don't need to be an electronics genius to get started turning everyday items into high-performing wonders. With how-to guru Dave Prochnow's step-by-step directions and fully illustrated plans, even beginners can hack their way to a high-tech home, cooler toys, and less yard work. Certain to fire your imagination and start you plotting new, original, and even more creative wonders you can make from ordinary household items, *Take This Stuff and Hack It!* is the perfect gift for your inner inventor. **$27.95**

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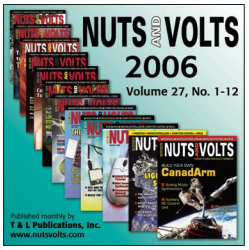

Here's some good news for *Nuts & Volts* readers! Along with all 24 issues of *Nuts & Volts* from the 2004 and 2005 calendar years, the 2006 issues are now available, as well. These CDs include all of Volumes 25, 26, and 27, issues 1-12, for a total of 36 issues (12 on each CD). These CD-ROMs are PC and Mac compatible. They require Adobe Acrobat Reader version 6 or above. Adobe Acrobat Reader version 7 is included on the discs. **$24.95 – Buy 2 or more at $19.95 each**

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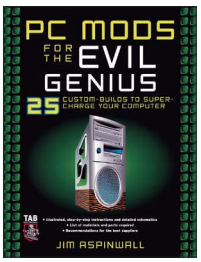
Are you ready for some good news? Along with the first 26 issues of *SERVO Magazine*, all issues from the 2006 calendar year are now available, as well. These CDs include all of Volume 1, issues 11-12, Volume 2, issues 1-12, Volume 3, issues 1-12, and Volume 4, issues 1-12, for a total of 23 issues all together. These CD-ROMs are PC and Mac compatible. They require Adobe Acrobat Reader version 6 or above. Adobe Acrobat Reader version 7 is included on the discs. **$24.95 – Buy 2 or more at $19.95 each**

HOME COMPUTERS

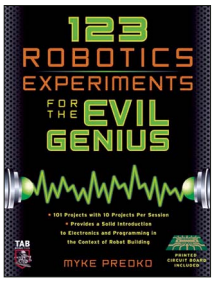
PC Mods for the Evil Genius
by Jim Aspinwall



If you yearn for the coolest, most crazed 'puter around, *PC Mods for the Evil Genius* is the key to the kingdom! This book shows you how to supercharge your PC and create a jaw-dropping system that cannot be purchased off any shelf, anywhere! You get complete, easy-to-follow plans, clear diagrams and schematics, and lists of parts and tools, so you know what's needed before you begin. **$24.95**

ROBOTICS

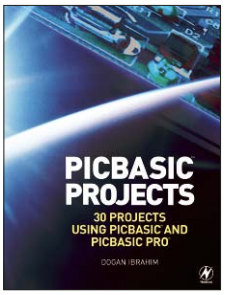
123 Robotics Experiments for the Evil Genius
by Myke Predko



If you enjoy tinkering in your workshop, you'll have hours of fun working through the 123 experiments found in this innovative project book. These exciting experiments also provide a solid grounding in robotics, electronics, and programming. Each one builds on the skills acquired in those before it so you develop a hands-on, nuts-and-bolts understanding of robotics — from the ground up. **$25.00**

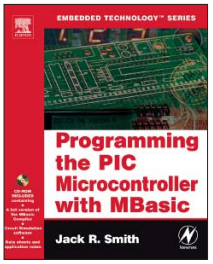
MICROCONTROLLERS

PIC Basic Projects
by Dogan Ibrahim



Covering the PIC BASIC and PIC BASIC PRO compilers, *PIC Basic Projects* provides an easy-to-use toolkit for developing applications with PIC BASIC. Numerous simple projects give clear and concrete examples of how PIC BASIC can be used to develop electronics applications, while larger and more advanced projects describe program operation in detail and give useful insights into developing more involved microcontroller applications. **$29.95**

Programming the PIC Microcontroller with MBASIC
by Jack Smith



No microcontroller is of any use without software to make it perform useful functions. This comprehensive reference focuses on designing with Microchip's mid-range PIC line using MBASIC, a powerful but easy to learn programming language. It illustrates MBASICs abilities through a series of design examples, beginning with simple PIC-based projects and proceeding through more advanced designs. **$59.95**

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■ BY PETER BEST

IN THE SHADOW OF THE 8051

I CAN RECALL MAKING THE "STEP UP" to the eight-bit 8051 from the venerable eight-bit 8048 way back when dinosaurs still roamed the plains and valleys. I chose to use the 8748, which was equipped with a quartz window to allow erasure of the EPROM that held the 8748's program instructions. I soon outgrew the 8748's 1KB of program EPROM and migrated to its big brother — the 8749 — which contained 2KB of on-chip EPROM under the quartz window.

On the application programming side of things, I seldom spilled out of the 2KB of EPROM offered by the 8749. However, I did have a tendency to wire in the then-popular 6116 2KB SRAM IC from time to time to augment the meager on-chip SRAM of the 8749. If my 8749 application included look-up tables that gobbled up the 2KB of EPROM, I would hang an external 4KB 2732 EPROM on the 8749's I/O pins. If things got bigger than that, too bad. The 8749's addressing engine maxed out at 4KB of program memory.

I remember being enthralled with memory banking at the time. More than once I lashed up an 8KB 2764 EPROM to an 8749 and used one of the 8749's general-purpose I/O lines to switch the EPROM's high address bit and thus switch between a pair of 4K EPROM banks. Yep, I did the same thing with 6164 SRAM. There was no way I had any use for that much SRAM space at the time, but it was fun to switch the SRAM banks, write a byte to a random location in that bank, and then write the code to read back the byte that I had written. Yes, I was easily amused.

As my appetite for programming the 8749 microcontrollers grew, the complexity of my 8749 applications followed in a linear fashion. I was attaching external analog-to-digital converters such as the ADC0809 to measure external voltages on things like NiCad battery packs and sealed lead-acid batteries. My dad wanted a "computerized" irrigation controller for his vineyard and, responding in kind, I assembled a timed valve controller around an 8749. I was also learning to communicate with other computing devices at this time.

I recall writing a soft-UART routine out of necessity as the 8749 didn't have an on-chip hardware UART. This was also before the MAX232 came into vogue. I serially interfaced my 8749-based devices to a green-screen dumb ASCII terminal using a pair of RS-232 converter ICs — the LM1488 and LM1489.

Personal computers were just beginning to hit the mainstream and my attention turned away from the green-screen dumb terminal to the colorful personal computer terminal emulator. As you can see, in my little world, the microcontroller independently ruled its domain and the personal computers and peripherals tried to stay on their side of the fence as much as they possibly could.

By now, my 8749 projects were beginning to eat up lots of perfboard real estate as I was hanging more and more peripheral stuff on the 8749's general-purpose I/O structure. There was no Internet then. Thus, I couldn't just pull up a search on the next best thing to the 8749. Luckily I had a friend, Bill Green, who was writing for *Popular Electronics* magazine at the time. Bill had "contacts" in the industry that fed him the latest information on new stuff coming onto the market.

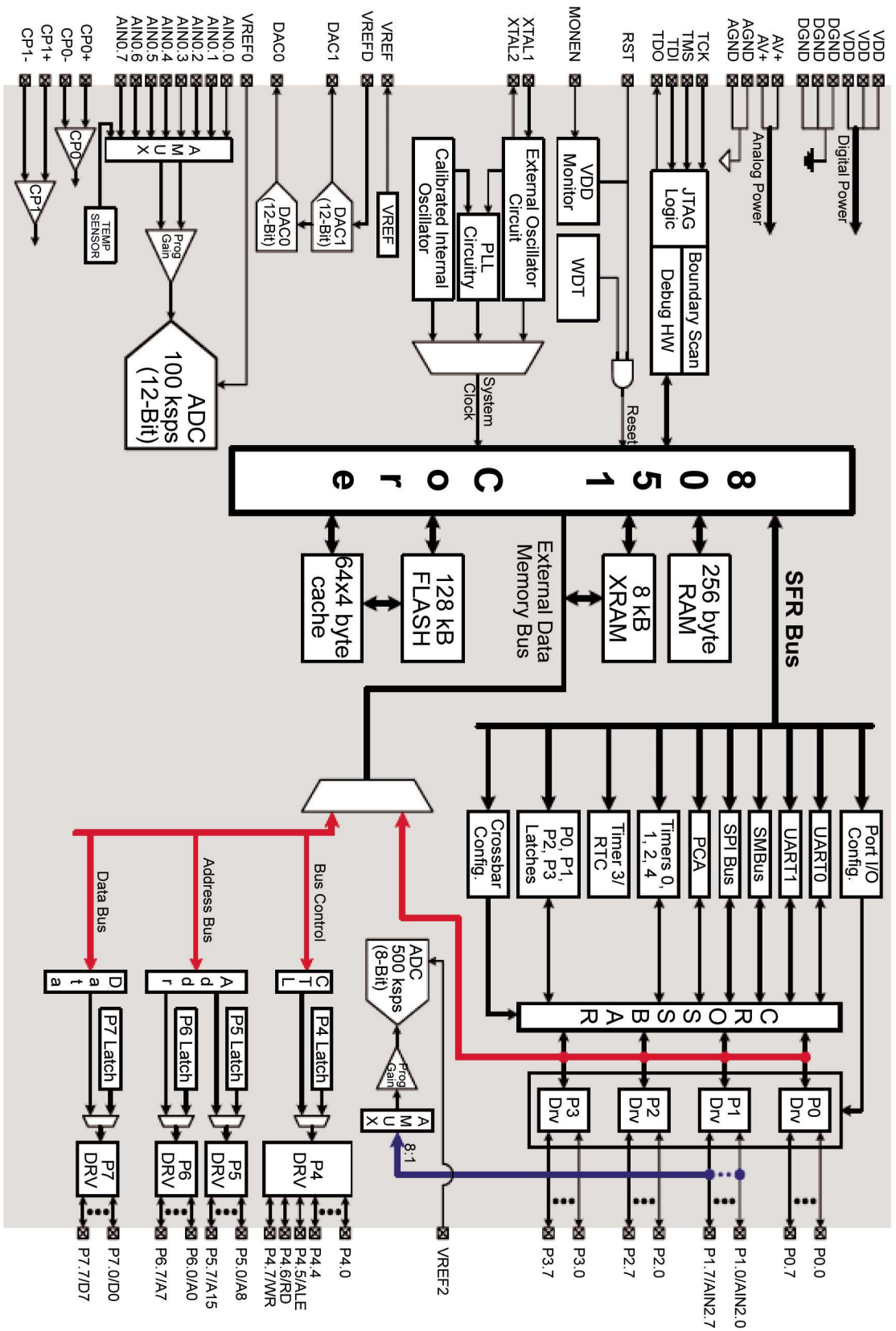
I recall flashing over a thing called a PIC and focusing on a bigger and better microcontroller, the 8051. I was already tooled up for the 8749 and I could get similar hardware programmer tools from the same source for the 8751. Ultimately, I ended up on a road trip to the nearest Intel field office (Atlanta, GA, for me — a three-hour drive one way) and purchased what was then a book describing the virtues of the 8051.

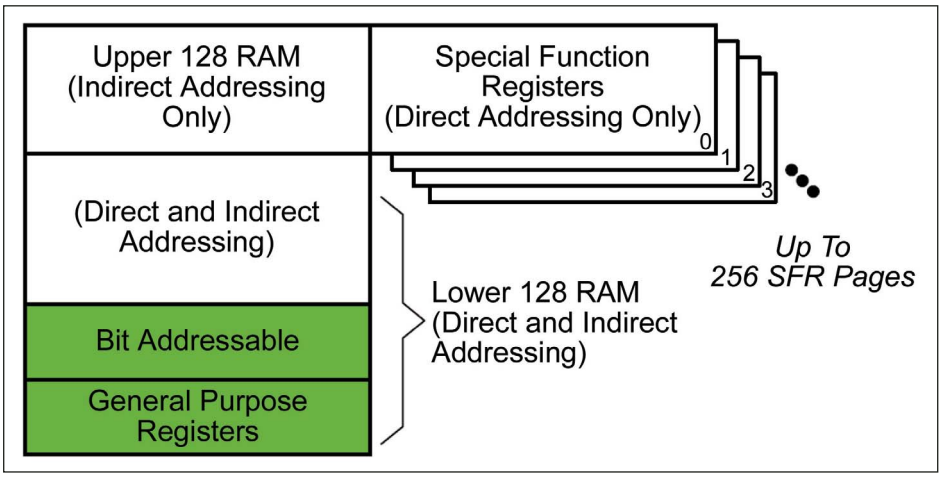
Note that I had to buy the 8051 databook. Back then, if you weren't part of General Motors or a large computing company, you were considered insignificant to the sales department and they sold you the stuff you needed at retail prices hoping you wouldn't come back.

I recall a buddy of mine that worked for Collins Avionics that had every databook that could be had from every major microcontroller manufacturer of the time. All he had to do was pick up the phone and ask the sales rep to drop by with the stuff he wanted. That used to really burn my butt. At least Bill shared any data he had with me on things I was interested in.

Well, I got my copy of the official Intel 8051 databook and thoroughly wore it out. For me, the 8749 was effectively dead. Another burr that turned

■ FIGURE 1. Take your time and take all of this in. The figure may seem busy at first, but after some study, you'll see that everything is arranged in a logical set of independent subsystems.





■ FIGURE 2. Don't get caught up in this too much as the Keil C compiler already has this little memory segment covered.

me away from considering the new PIC at that time was that the Microchip sales rep wanted to sell me the PIC assembler for $99. I had been using a shareware version of the 8749 assembler and it worked for me. I had already found an 8051 shareware assembler and I was not about to drop a C-note to "buy" an assembler for that PIC thing. As far as I was concerned, I was moving to the 8051 platform right on time as 8749's were almost impossible to buy new and the used surplus 8749s were getting hard to procure, as well.

I was still stuck with only 4KB of program EPROM with the 8051. However, the 8051's addressing engine was 16-bits wide providing me with 64KB of space that I could populate with a combination of EPROM and SRAM. Just as I did with the 8749, I standardized all of my projects on the quartz window-equipped 8751. I was already used to rotating multiple 8749 parts through the EPROM eraser to speed up my development and the 8751 offered no advantage in this department.

One would think that an increase in program execution speed would come automatically with the 8751. With a strong tailwind, an 8749 running with an 11 MHz clock could pump out 0.5 MIPS. The 8751 doesn't do much better with the same tailwind and a 12 MHz clock. The bottleneck for both the 8749 and 8751 was the large number of clock cycles needed to execute an instruction.

I may not have picked up any execution speed, but I did get some other things that made moving to the 8751 worthwhile. A feature of the 8751 that I found intriguing was its ability to perform internal Boolean processing on a bit level within it registers. I was also able to archive my bit-bang serial routines as the 8751 was endowed with a hardware UART. I wasn't really keen on using interrupts at the time, but if I had been, the 8751 allowed the programmer to use separate register sets to store interrupt context information instead of having to push and pop important registers from a stack.

My crowing achievement was an 8751-based musical instrument tuner that utilized the 8751's timers. After that project, I moved on to other microcontrollers that easily outpaced the 8751 in speed, general-purpose I/O, and on-chip peripherals. Microchip decided that maybe their assembler should be free for customers that used the PIC parts. I was still mad at Microchip. Along the way, the Zilog Z80 had gotten my rapt attention. Bill loved the Z80 and thus, Z80 information and application notes were very easy for me to obtain. So, I rode the Z80 bus for quite some time.

HERE WE ARE

The concept of the 8051 hasn't changed but the way the 8051 concept is applied has changed exponentially. As you might imagine, I see lots of interesting stuff pass across the benches at EDTP Electronics. One of the many variants of the 8051 that caught my eye was the Silicon Laboratories C8051F120. Just a cursory glance at Figure 1 speaks volumes. An 8KB bank of SRAM coupled with a separate 256-byte SRAM bank easily eclipses the old 8751 memory model.

Unless you're writing navigation and targeting code for an F-18 Hornet fighter/bomber, the C8051F120's 128KB of program memory should cover most of your (and my) 8051-based applications. Throw away that EPROM eraser as the C8051F120's program memory is made up of electrically-erasable Flash not EPROM. And, we won't need the services of those ADC0809 analog-to-digital converters as the C8051F120 incorporates its own on-chip multi-input analog-to-digital converter subsystem.

Note that I never mentioned debugging the 8749 or 8751 as the original 8048/8051 emulators were priced in the multi-thousands of dollars. I'll bet GM still has an 8048 emulator stuffed away somewhere in a warehouse.

I don't know how many of you did the write-the-code, program-it, test-it, erase-it, correct-the-code, program-it, test-it, erase-it 8749/8751 vicious design cycle like I did. It was a necessary evil as I couldn't afford the 8749/8751 debugging hardware. In my opinion, the C8051F120 offers one of the most comprehensive and easy-to-use debugging systems. That translates to super easy C8051F120 development cycles. Oh yeah, I wrote all of that 8749 and 8751 code in assembler. We will be writing our C8051F120 code in C.

The C8051F120 is based on Silicon Laboratories' proprietary CIP-51 microcontroller core. The Silicon Laboratories' CIP-51 is fully compatible with the original tried-and-true 8051 instruction set. This allows any standard 8051 assembler or compiler to be used to develop C8051F120 firmware.

With the old 8051 cores, we could only dream of achieving throughputs above 0.5 MIPS. The Silicon Laboratories' CIP-51 employs a pipelined architecture that greatly increases its instruction throughput over the old 8751's I was burning and churning.

In a standard 8051, all instructions except for MUL and DIV take 12 or

24 system clock cycles to execute. The Silicon Laboratories' CIP-51 core executes 70% of its instructions in one or two system clock cycles, with only four of 190 instructions taking more than four system clock cycles. The old 8751 could only crank up 0.5 MIPS with a 12 MHz clock. The Silicon Laboratories' CIP-51 core can peak at 100 MIPS when powered by its PLL-assisted 100 MHz clock.

There are plenty of C8051F120 on-chip gadgets we can put to work in an application. However, if we don't have our arms around the C8051F120 basics, we won't even be able to blink an LED. So, let's examine the C8051F120's basic subsystems.

C8051F120 MEMORY ORGANIZATION

Even though the Silicon Laboratories' CIP-51 is a proprietary implementation, it has a standard 8051 program and data address configuration. A standard 8051 addressing configuration consists of 256 bytes of data RAM, with the upper 128 bytes being dual-mapped. Indirect addressing accesses the upper 128 bytes of general-purpose RAM, and direct addressing accesses the 128 byte SFR address space. The lower 128 bytes of RAM are accessible via direct and indirect addressing.

The first 32 bytes are addressable as four banks of general-purpose registers, and the next 16 bytes can be byte addressable or bit addressable. When I first encountered this small segment of memory, I had to really think about what was going on as I was writing my code in assembler. Don't get too caught up in the seeming complexity as the Keil 8051 C compiler we'll be using takes care of us in this area. What you see in Figure 2 describing the C8051F120 256-byte RAM segment layout is enough for now.

The Silicon Laboratories C8051F120 devices include an on-chip 8KB RAM block and an external memory interface (EMIF) for accessing off-chip data memory. Using overlapping 8KB boundaries, the on-chip 8KB RAM block can be addressed over the entire 64KB external data memory address range. External data memory address space can be mapped to allow the programmer to use only the on-chip memory or a combination of on-chip and external memory.

For instance, addresses up to the 8KB boundary can be directed to on-chip memory and any addresses above the 8KB address marker are directed to EMIF. If you're using external memory that multiplexes the address and data lines, the EMIF can be configured to accommodate multiplexed address/data lines. Figure 3 is a graphical depiction of the C8051F120's external RAM space.

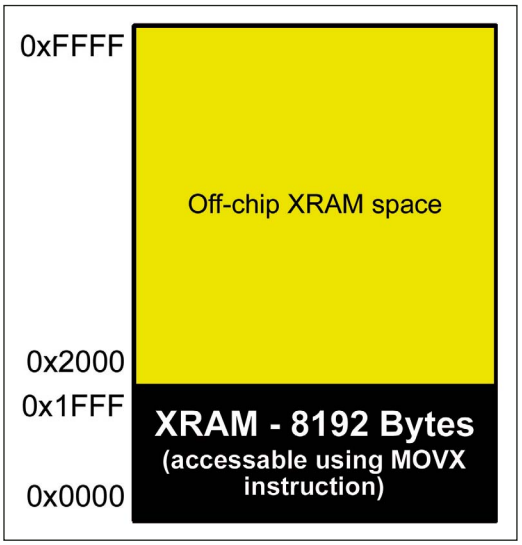
The C8051F120's program memory consists of 128KB of banked Flash memory. As you can see in Figure 4, the 1024 bytes between addresses 0x1FC00 and 0x1FFFF are reserved. This memory may be reprogrammed in-system in 1024 byte sectors, and requires no special off-chip programming voltage. Notice that there are also two 128-byte sectors beginning at address 0x20000 and ending at address 0x200FF, which may be used by the programmer for data storage. Again, this memory map information is good for the head and is taken care of for you by a good C compiler.

C8051F120 I/O AND DIGITAL CROSSBAR

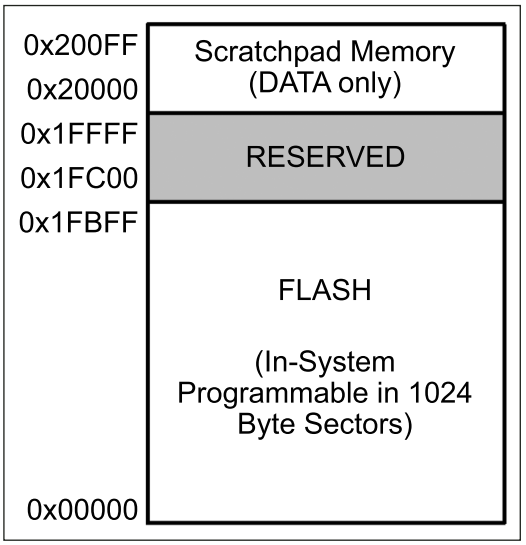
The standard 8051 configuration offers a total of four eight-bit ports (0, 1, 2, and 3). The C8051F120 is packaged in a 100-pin TQFP format, which allows for four additional ports (4, 5, 6, and 7). It is not every day you see a microcontroller that allows you to configure the actual internal port hardware. The C8051F120's general-purpose I/O operates in an identical manner to the standard 8051, but better.

Each of the C8051F120's general-purpose I/O pins can be configured as either a push-pull or open-drain output. Power savings wasn't as big a deal in the old days as it is now. The standard 8051 configuration permanently enabled "weak pullups." The C8051F120 allows the "weak pullups" to be globally disabled, allowing the C8051F120 to play in today's low-power application environments.

Take another look at Figure 1. Do you see all of those on-chip peripherals feeding the Digital Crossbar? The Digital Crossbar is nothing more than a large on-chip digital switching network that allows the mapping of internal C8051F120 digital system resources to C8051F120 general-purpose I/O pins on P0, P1, P2, and



■ FIGURE 3. The bottom line is that you can configure the usage of this space to suit you.



■ FIGURE 4. As Grace Slick would say, "Feed your head." You can muck around with your linker to put stuff where you want it in this space. However, it's easier to let the compiler do it for you.

SOURCES

■ *Silicon Laboratories* (**www.silabs.com**) — C8051F120; C8051F120 Development Board

■ *Keil* (**www.keil.com**) — Keil uVison3 C Compiler

P3. What you would normally encounter with most other microcontrollers here is a multiplexing scheme, which allows predetermined system resources to share predetermined general-purpose I/O pins. The Digital Crossbar approach allows all of the combinations of all functions. The on-chip counter/timers, serial buses, HW interrupts, ADC Start of Conversion inputs, comparator outputs, and other digital signals in the controller can be configured to appear on the C8051F120 general-purpose I/O pins specified in the Crossbar Control registers.

I'm not going to insult your intelligence as I'm positive that many — if not most — of you have configured and used a microcontroller UART. Most of you are also already familiar with how microcontroller timers operate. So, let's take command of the C8051F120 and all it has to offer.

TOOLING UP

When it comes to 8051 C compilers, you will have to look hard to beat Keil's uVision3 8051. The Keil 8051 C compiler includes native support for the Silicon Laboratories' C8051F120. Just in case you're wondering why I didn't go into excruciating detail about the C8051F120's internals and memory areas, Listing 1 shows an excerpt from the C8051F120 include file (c8051f120.h) that is part of the Keil 8051 C compiler.

It's pretty obvious that the include file excerpt is a man-to-machine mapping of some of the C8051F120's SFRs (Special Function Registers). I purposely picked out the Digital Crossbar definitions to give you an idea of how to address the Digital Crossbar's configuration registers. Let's walk through a very simple example of Digital Crossbar configuration. Our goal is to enable general-purpose I/O P1.6 as a push-pull output that will drive an LED. Push-pull configuration of the general-purpose I/O port means that when we write a logical 1 to the port pin, the output of the port pin will go logically high. Conversely, a logical low I/O instruction from the application will render a logical low at the targeted general-purpose I/O pin output.

The following two lines of code take advantage of the reset conditions of the XBR0, XBR1, and XBR2:

```
XBR2   = 0x40;      // Enable crossbar and weak pull-ups
P1MDOUT |= 0x40;    // enable P1.6 (LED) as push-pull output
```

The bits contained within XBR0 enable or disable the Comparator 0 output, the PCA0 module, UART0, SPI0, and SMBus0. The corresponding bit in XBR0 must be set to enable the peripheral represented by the bit. XBR0 resets with all of its bits cleared. Thus, every internal peripheral represented in XBR0 is disabled on reset. We're only interested in defining a single push-pull output and none of the peripherals represented by XBR0 need to be involved. XBR1's bits deal with interrupt inputs, among other things, and we don't need any of that right now, either. So, we leave XBR1 in its reset state, which is all bits cleared and all corresponding services represented by the bits disabled. I think you get the idea.

However, XBR2 houses the "weak pullup" bit, which is enabled when the bit is clear. Thus, all we're doing by setting that single bit within XBR2 is to enable the Digital Crossbar. Once the Digital Crossbar is enabled, we can set the bit within the P1MDOUT SFR that configures general-purpose I/O pin P1.6 as a push-pull output. If we were to hang an LED on general-purpose I/O P1.6 in a sourced configuration (LED cathode grounded), issuing an application command to send a logical 1 to the P1.6 general-purpose I/O pin would illuminate the LED.

The thing you want to take away from this is that following a reset, you won't have to worry about turning off Digital Crossbar stuff you don't need in your application. All you have to do is enable the internal peripherals you intend to use and turn on the Digital Crossbar if necessary.

NEXT TIME

Normally, we're on the scent of assembling and coding a particular application. Not so this time. So, we'll explore the capabilities of the C8051F120 using an off-the-shelf Silicon Laboratories' C8051F120 development board. That will allow me to use the excellent Silicon Laboratories debugging/programming device in conjunction with Keil uVision3 to show you how things C8051F120 work at the bit level.

The C8051F120's innards have been partially exposed. We still have C8051F120 timers, UARTs, capture modules, comparators, and such to work through physically and logically. You will come to realize that the ease of dealing with the C8051F120's Digital Crossbar flows across all of the C8051F120's internal peripherals. The C8051F120 is a very powerful mixed-signal SOC (System on a Chip). Just because the C8051F120 is powerful doesn't mean it has to be difficult to use. I'll prove that to you in the next installment of the Design Cycle. **NV**

LISTING 1

```
sfr P4MDOUT     = 0x9C;     /* PORT 4 OUTPUT MODE                          */
sfr SPI0CKR     = 0x9D;     /* SPI 0 CLOCK RATE CONTROL                    */
sfr P5MDOUT     = 0x9D;     /* PORT 5 OUTPUT MODE                          */
sfr P6MDOUT     = 0x9E;     /* PORT 6 OUTPUT MODE                          */
sfr P7MDOUT     = 0x9F;     /* PORT 7 OUTPUT MODE                          */
sfr XBR0        = 0xE1;     /* CROSSBAR CONFIGURATION REGISTER 0           */
sfr PCA0CPH5    = 0xE2;     /* PCA 0 MODULE 5 CAPTURE/COMPARE - HIGH BYTE  */
sfr XBR1        = 0xE2;     /* CROSSBAR CONFIGURATION REGISTER 1           */
sfr XBR2        = 0xE3;     /* CROSSBAR CONFIGURATION REGISTER 2           */
sfr EIE1        = 0xE6;     /* EXTERNAL INTERRUPT ENABLE 1                 */
```

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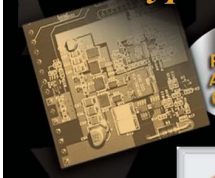

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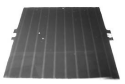

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BY LOUIS E. FRENZEL W5LEF

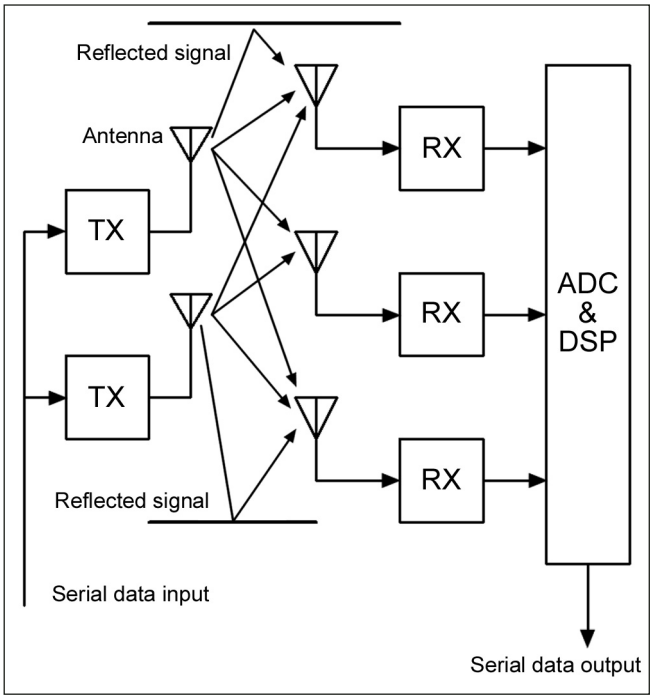
MIMO 101: Next Generation Wireless Technology is Finding Its Way Into Most New Systems

IN CASE YOU HAVEN'T HEARD, MIMO means Multiple Input Multiple Output which — by itself — still does not explain very much. It is a relatively new wireless technique that makes use of two or more transmitters, receivers, and antennas to greatly improve the range, reliability, and data rate of digital wireless systems. It is being incorporated in the newest versions of wireless LANs and in the new metropolitan (metro) wireless systems like WiMAX. And it could play a role in future cell phone systems. You can expect to see it soon in a wireless system that you use. That's why you should know more about it.

MIMO SOLVES SOME REAL PROBLEMS

In modern digital wireless systems, the goal is always to transmit data faster over a longer distance with greater reliability. That's a tough job. It is particularly difficult at microwave frequencies where most digital transmissions take place. Remember that microwave frequencies are those above 1 GHz. This is where the wireless local area networks (WLAN) like Wi-Fi IEEE 802.11 standard-based units work. The 2.4 GHz band is the most common, but 5.8 GHz is also used. Data transmissions in cell phones for Internet access, email, instant messaging, and the like take place just below 1 GHz in the 850 to 965 MHz range and in the 1.8 to 2.1 GHz range.

In these frequency ranges, signals are easily reflected, refracted, diffused, absorbed, and otherwise affected by their environment. Buildings, walls and ceilings, trees, passing cars, or planes all affect the signal. What happens is that a transmitted signal goes directly to the receiver but signals reflected from other sources also end up at the receiver. Since the reflected signals take a longer path to the receiver, they occur at a slightly later time so the effect is to cancel some of the directly received signal. The multipath signals cause fading and signal attenuation. And that effect is not just an occasional thing but an all-the-time thing. Highly directional antennas — like Yagis and parabolic dishes — can help in fixed point-to-point applications, but you can't put



■ FIGURE 1. The basic concept of MIMO showing a 2x3 arrangement of transmitters (TX) and receivers (RX). The receiver outputs are digitized in analog-to-digital converters (ADC) and then manipulated by a digital signal processor (DSP) to combine multipath signals. The result is higher data rates over longer distances with greater reliability.

these on mobile devices like cell phones or laptops.

One way to improve this situation is to use an old radio technique called diversity reception. The receiver is set up with two or more antennas spaced as far apart as possible. A spacing of one wavelength or more is desired, but the technique will work with less spacing, but less effectively. At microwave frequencies, this is not a problem because one wavelength is pretty short.

For example, one wavelength at 2.4 GHz is about five inches. With two antennas spaced this far apart, they both receive the signal but most likely from different directions via different paths and reflections. The receiver is then set up to select the strongest signal by switching to the antenna with the greatest signal strength. In some diversity systems, the signals from the antennas can be combined assuming they don't cancel one another. Cordless phones, most WLAN units, and most cell phone base stations use diversity to improve reception.

MIMO IMPROVES ON DIVERSITY

MIMO (pronounced "my mo") systems use diversity, as well as other techniques to further improve signal strength and reliability of reception in the face of multipath effects. It goes further, however, in that it also improves data rate. MIMO makes use of a minimum of two transmitters (TX) and two receivers (RX). In many cases, more receivers are used. A common arrangement is two transmitters and three receivers or what we call a 2x3 MIMO system (see Figure 1).

The data to be transmitted is divided into two separate but simultaneous data streams and modulated on to the two transmitters. The most widely used modulation method is orthogonal frequency division multiplexing (OFDM) with some form of PSK or QAM. These transmitters send the data out over the same frequency at the same time, but special digital coding methods are used to keep the signals unique so the receivers can separate them out. What this simultaneous transmission does is to effectively double the highest possible data rate. For example, a 54 Mbps rate on both transmitters gives a net overall data rate of 108 Mbps at the receiver.

At the receive end of the system, the three receivers with separate antennas spaced as far apart as possible pick up the direct signals, as well as all manner of reflected multipath signals. The signals received at each antenna are different. What the MIMO system does is to make use of all the received signals to improve reception. This is done by digitizing each received signal in an analog-to-digital converter (ADC) then sending the result to a digital signal processor (DSP).

Special computing algorithms then manipulate the signals so as to combine them to produce receive gain and to virtually eliminate the fading problem. What the MIMO method does, in effect, is to use all the received signals — reflected or otherwise — and combine them to produce an overall increased signal level. This extends not only the range of the signal but also improves overall reliability of the transmission in common multipath environments.

MIMO sounds expensive because it uses multiple transmitters, receivers, and antennas. That may have been a problem at one time, but today with the available integrated circuits, MIMO is affordable and very small. Special MIMO chipsets put two and sometimes even more transmitters on a chip, as well as three or more receivers. Semiconductor process technology lets designers easily incorporate the DSP and other circuitry directly on a single chip. Small antennas make it easy to place two or three on a MIMO product.

WHERE IT IS USED

The first widespread use of MIMO is in WLANs. It is available in the wireless access points (APs) and gateways and inside laptop computers. It is being incorporated in the latest version of the IEEE 802.11 WLAN standard. The most widely used current standard is 802.11b and 11g. The 11b version is the oldest, operates in the 2.4 GHz band with direct sequency spread spectrum (DSSS), and gives 11 Mbps at a range to 100 meters. The 11g standard also works in the 2.4 GHz band but uses OFDM and supports data rates to 54 Mbps up to 100 meters. A lesser used standard is 802.11a which works in the 5.8 GHz band and uses OFDM to give up to 54 Mbps.

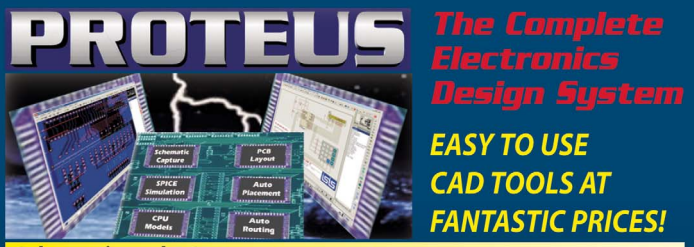
The IEEE is currently working to finalize the next version which is 802.11n. A final version is not expected to be ratified until early 2008. In the meantime, chip vendors and Wi-Fi equipment vendors are offering a pre-n or draft-n version of the standard. The 11n standard incorporates MIMO. The Wi-Fi Alliance who certifies 802.11 products for interoperability is even certifying pre-n versions of the equipment. The most common configuration is the 2x3 version with two transmitters and three receivers. A typical unit is shown in Figure 2.

■ FIGURE 2. A Belkin pre-n router uses MIMO in home and office networks. It is backwards compatible with 802.11b/g Wi-Fi WLANs. While speed is improved, its real value seems to lie in its extended range and increased radio link reliability. Photo courtesy of Belkin Corporation.

The final 11n units will deliver a data rate of over 200 Mbps up to 100 meters with greatly improved reliability. It is this version of the standard that is expected to be widely used to distribute video in home networks when Internet Protocol TV becomes available this year and beyond.

MIMO is also expected to be used with WiMAX. This is the name of the IEEE 802.16 wireless metro area network. It is not widely available yet, but is being built now as a wireless broadband service to provide high speed Internet service to those in rural areas with no DSL or cable. Many even expect WiMAX to be used for wireless voice over Internet protocol (VoIP) telephone calls that compete with cellular. Some even see WiMAX as the fourth generation (4G) of cellular, but that remains to be seen. In any case, WiMAX works in the 2.4-2.7 and 3.5 GHz bands so it's a great choice for MIMO.

MIMO is more difficult to integrate into cell phones because they are so small and make antenna placement and spacing a major problem. MIMO is used in base stations and that usage will expand in the future. MIMO will show up in laptops where it is possible to mount and hide two or more antennas. MIMO is a great wireless technique and available now because of the power of digital signal processing. **NV**



 Continued from Page 47

FLYIN' HIGH FOR NEAR SPACE

As an engineer and experimenter, I have found myself very interested in Paul Verhage's articles. As an ex-commercial pilot and sometimes almost daily commercial jet passenger, I am interested in the regulatory and safety aspects of his hobby.

His work is very stimulating and it reminds me of some projects I'd like to tackle if I knew more about how to get started. I know where to get the helium and the balloons but late at night, at FL37, sometimes I think about the sound of one of Verhage's balloons going through the compressor of a Rolls or Garrett engine :>).

In all seriousness, I would like to get much more information about the safe way to approach this hobby.

Larry Cagle

GETTING GROUNDED

I was just reading the current edition and came across the Q&A on grounds, and why chassis ground is called chassis ground.

In the days of tube radios and televisions, most — if not all — of the chassis were made of tin or formed metal; the majority of wiring on those old tube sets was single wire with the return path being the chassis. On some houses, one had to be careful with the plug because if you plugged it in upside down, the chassis would be hot. I have been buzzed numerous times from a hot chassis.

Earth ground was indeed referenced to Earth and mostly had to do with antennas since Earth formed half of a Marconi or Hertz antenna.

Electrical circuits were not referenced to Earth in a lot of early construction; some of the earliest wiring was floating with either side to Earth at 65 volts and phase-to-phase at 130 volts. Again a hot chassis, but it would not shock you since the wiring was not ground referenced.

If the building had grounded construction, it would be at the fuse panel with a ground rod connected to the neutral. Sometimes they just used a cold water pipe; I have even seen it done tied into the telephone ground rod. Since ground was not carried in the wiring, there were no three-wire outlets, and only the very newest construction had outlets that would accept a polarized plug and had a ground referenced system. Most early (before polarized) plugs had both tabs the same size. When polarized plugs were introduced, most cut off the extra wide tabs because they would not fit the old duplex receptacle, hence the statement about a hot chassis above.

Pat Goodyear

STUDENT NEEDS HELP PICing

I am an electronics student, and, though I've been playing around with stuff since I was about eight years old, I'm just getting started — this being my first post-secondary year. Being a programmer, I am interested in getting into PICs, mainly since I found out that Microchip gives out free samples ;). I was hoping you could point me to a cheap programmer for them. It can be USB or COM, kit or assembled, but not too hard to build if it is a kit. I would like to be able (if possible) to program a range of PIC models. Could you point me to some products, please?

Jeff MacEachern

Author Response:

I get this question often. There are lots of choices including programmers on eBay. I even offer a PIC programmer kit at my website ***www.elproducts.com*** *for $19.95 that is easy to build and is powered off the serial port of a computer. But most people want a USB programmer though, since many computers don't even offer serial ports anymore.*

Because of that, I wrote a summary on the various USB PIC programmers in the October '06 Nuts & Volts issue. If you can get a hold of that, it might help you make the decision. In the article, I included the PICkit2 USB powered programmer from Microchip at ***MicrochipDirect.com*** *and after using it for a while, I've found it's one of the best. It's not a kit though, since it comes fully assembled and even includes a development board and PIC16F690 for $50. It also includes sample compilers and free sample programs.*

In the March '07 N&V issue, I use the PICkit2 to do in-circuit programming which is something you'll want to learn. So, my kit or PICkit2 would be my recommendation.

Chuck Hellebuyck

PATENTED ANSWER

I'd like to note some inaccuracies in the Feb '07 article "Open Communication" p.88-89; Julius Lilienfeld invented and patented the transistor in the early 1930s:

Pat #1,745,175 Jan 28, 1930
Pat #1,877,140 Sep 13, 1932
Pat #1,900,018 Mar 7, 1933

Reading the patents shows that he clearly knew what he was doing.

Remember, at that time, the Great Depression was rolling and funds for developing a device from an "unknown" were not available.

I think that the records show that Shockley et al. were well aware of those patents!

Author Response:

Thanks for your input on my Feb Nuts & Volts column. You are right about Lilienfeld being the first to invent the transistor. In fact, it was actually a field effect transistor and not the point contact and BJT that Shockley and his crew came up with. But as I have read, Lilienfeld never did actually build and test one. Nevertheless, I agree that the patents tell the story. The situation is not unlike the story I told in the article. Tesla gets the patents, but Marconi gets all the fame and money.

I just went with the conventionally accepted wisdom that the transistor was invented at Bell Labs. Lilienfeld was certainly first, however. I acknowledge that. I appreciate you writing.

Lou Frenzel

TECH FORUM

This is a READER-TO-READER Column.

All questions *AND* answers are submitted by *Nuts & Volts* readers and are intended to promote the exchange of ideas and provide assistance for solving problems of a technical nature. Questions are subject to editing and will be published on a space available basis if deemed suitable by the publisher. Answers are submitted by readers and NO GUARANTEES WHATSOEVER are made by the publisher. The implementation of any answer printed in this column may require varying degrees of technical experience and should only be attempted by qualified individuals. Always use common sense and good judgement!

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QUESTIONS

To be considered, all questions should relate to one or more of the following:

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❸ Problem Solving
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>>> QUESTIONS

I would like to know if I can hook up a Velleman K4003 amplifier to my speakers directly to increase volume and what does the circuit wiring entail.

#4071 Paul Kozlowski
Schertz, TX

I'm looking to build a battery charger that can continuously charge a battery under load – such as you would find in an online UPS.

I'm not sure how this would differ from a regular continuous maintenance charger (i.e., a charger that supplies a trickle charge, as well as periodic higher power plate cleaning charges). Any guidance would be appreciated.

#4072 Don Stahl
via email

I am in the process of restoring an older Chevrolet truck (1957) and would like to put in high intensity discharge (HID) headlights like some of the high-end automobiles now have. I'm looking for schematics, pointers, and any other information on the ballast/control circuit to drive them.

#4073 John Blankenagel
Hillsboro, OR

I've got an older computer (PIII at 500 MHz) and would like to add a larger hard drive (250 GB @ ATA133 or a 200 GB @ ATA100). I have been told by some that the computer won't be able to access the new drive's entire capacity and won't be supported by the micro-ATX motherboard (GT440ZX). Presently, its 'primary' hard drive is a 27.2GB U-DMA ATA-66 which is now full (OS=WIN98SE). I would like to copy all the files on it and replace it with the larger drive.

If I install the 250 GB, will I be able to access the entire capacity and will it be supported by my existing motherboard or will I have problems?

Also, I need a recommendation for software which will allow me to copy ("mirror") and move all my files from one drive to the other.

#4074 Michael Williams
via email

I have a project that requires two power amplifiers capable of driving very low impedance AC motors. The specs for the motors are 120 VAC at 4A. The motors will have the armature removed as I am using only the field assemblies in a magnetic amplifier. The drive for the motors is two sine waves and the output of the magnetic amplifier needs to be the sine wave sum of the inputs.

I will use a dual channel Direct Digital Synthesizer from *Nuts & Volts* Nov '06, page 48. I will drive the motors from near 0 Hz to about 50 kHz with the two inputs separated by

various frequencies.

#4075 Orval Hollingsworth
Rocklin, CA
buzzholl@starstream.net

Can anyone recommend a decent electronics glossary of terms or dictionary?

#4076 Paul Kozlowski
Schertz, TX

>>> ANSWERS

I am new to programming and need some advice on which assembly code is better to start out on. What book (or books) should I get?

#1 If you're new to programming, there are two types of programming to choose from. The first is procedural (which includes assembly); the second is object orientated. Object Orientated Programming (OOP) can easily be learned by downloading Express Editions of Visual Studio (for free) from Microsoft; along with numerous code samples and support information (from MSDN, also free); there are a lot of beginning programming books available for this platform. OOP has the advantage that it is the standard for corporate development.

The primary reason to learn assembly is for speed and absolute access to the physical hardware. If you don't need both of these, learning a language like C might work out better for you. C is almost as fast as assembly and has the advantage that you can use it across various platforms. There are a lot of very good books for beginners for it, as well.

If you're still set on learning assembly; the first thing you need to pick is your processor. Unless you already have a platform in mind, I would suggest picking one of these three: Microchip PIC microcontrollers; Atmel ARM microcontrollers; and TI MSP microcontrollers.

My personal recommendation is the TI product; the development environment is only $20, which includes a USB programmer, Flash-based processor board, and all the development software. In addition, the assembly language itself is very robust and easy to understand, and the kit includes a wealth of code examples. Once you've learned one assembly language, learning a second is much easier since you only have to learn how the mnemonics are different.

If this is just for fun, then I would suggest getting an Apple II+ emulator off the Internet (like AppleWin) and a 6502 assembly language tutor book from Amazon. These books are very education focused, plus, you can play classic Apple games while learning.

Joe O'Brien
Ladera Ranch, CA

#2 You didn't mention which particular processor or microcontroller for which you would like to learn assembly. I will assume that you would be interested in the PIC microcontrollers manufactured by Microchip.

The first resource you will want to consider is the manufacturer's website, **www.microchip.com**. Here, you will find a wealth of knowledge in the form of reference manuals, device datasheets, and application notes. Also, be sure to download the MPLAB Integrated Development Environment. This free software package includes a simulator which allows you to single-step through each line of code and examine the results. This can be a very valuable tool in understanding how a particular microcontroller works.

Myke Predko has written an in-depth book (nearly 1,200 pages) entitled "Programming and Customizing PICmicro Microcontrollers." This book starts with the basics and provides

[#1073 - January 2007]

I have an antique tractor that has a 6 VDC electrical system. Because this tractor is not used like the daily workhorse it once was, I have to charge the battery every month or so. I can find 12 VDC float chargers; and, in fact, use these $15 gems to maintain most of my lead-acid batteries. Can you provide me a circuit that will maintain the voltage of 6 VDC lead-acid batteries? The circuit would stay plugged into the 110 VAC mains and monitor the battery voltage.

#1 I have an Enerwatt 612-900 that would do what you ask. It looks like a larger-than-normal wall-wart, and comes with clamps and ring terminals.

It charges 6 or 12 volt lead-acid batteries with three stage charging and is designed to be left on the battery indefinitely.

I paid about $35 (Canadian) for it, and it's available from Prairie Battery (**www.prairiebattery.ca**).

Andy Fenstad
Winnipeg, Manitoba

#2 I have not built this, but I carefully checked the ratings. The fuse is 5 X 20 mm and is to be mounted on perf board using two fuse clips. I chose 315 mA because it is a size used in meters and is readily available. The transformer has wire leads and can be bolted to the chassis or perf board. The parts were chosen to be able to be mounted on perf board or a RadioShack project board. The red LED is just to show that power is on.

The circuit in Figure 1 operates this way: R2 and D1, D2 limit the current through the TIP41 to about one amp. It would take a week to charge a dead battery with this circuit, so it is not a fast charger, but when the battery is charged, it will maintain it. When the battery voltage rises to 6.8 volts, the PN2222 is turned on, which lights the green LED and shuts down the TIP41. The circuit will

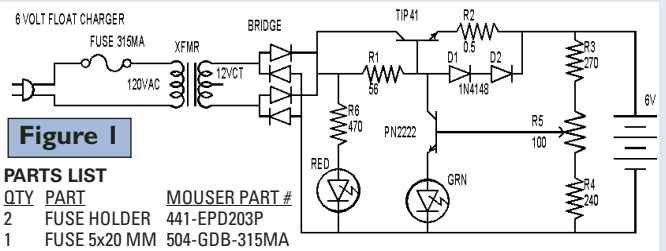

Figure 1

PARTS LIST

QTY	PART	MOUSER PART #
2	FUSE HOLDER	441-EPD203P
1	FUSE 5x20 MM	504-GDB-315MA
1	XFMR	41FG010
1	BRIDGE	627-S1VB20-7000
1	R6 1/4W	291-470-RC
1	R1 1/2W	293-56-RC
1	TIP41	511-TIP41CN
1	R2 1/2W	293-0.5-RC
2	D1, D2	78-1N4148

QTY	PART	MOUSER PART #
1	PN2222	512-PN2222TA
1	GRN LED	604-WP7104SGD
1	RED LED	604-WP63SRD
1	R3 1/4W	291-270-RC
1	R4 1/4W	291-240-RC
1	100 OHM POT	652-3352E-1-101LF

many examples. After the manufacturer's published literature, some people consider this book to be the definitive resource.

And finally, if you get stuck, there are a variety of online resources for you to ask specific questions. Microchip has their own online forums and you should also check out the MIT PICList email list at **www.piclist.com**.

Aaron Garber
Arcanum, OH

#3 Start with a simple microcomputer like the PIC with only 33 instructions to learn.

You might start out with a microcomputer simulator. It is a piece of software that runs on your PC and looks like a micro. There is a window where you write code; "move A,B" and other windows where you see the number move from B to A or A to B, as you will soon know. Microchip MPLAB is free; a number of companies give away their development software.

If you want to go straight to hardware, search for the BASIC Stamp (as there are many competitors). You write in Basic (some allow assembly), but you have a tiny computer up and working in minutes. There are hundreds of examples of working code and good help forums.

Go to any microcomputer website. MicroChip, TI, Zilog, Silicon Labs, Atmel, etc., and look for development boards. You need a board with a microcomputer, LEDs, buttons, and places to add more parts. I have SiLabs C8051F005 development kit that comes with a good simulator/compiler. SiLabs and TI have boards as small as your thumb. Mikroe.com has beautiful large boards. Good luck!

Ron Simpson
Loveland, CO

#4 Programming is a large topic, so the answer will be a bit general. Here is a quick run-down of the basics and places to look.

The most important thing to know is that learning a language is only a small part of programming. Understanding algorithms, data structures (how to store and access data), and overall design are extremely important when writing programs with more than a few hundred lines of code. I'd recommend getting a book on data structures and another on software engineering (that's the fancy term for planning and managing program development).

As for the actual languages to learn, programming for computers is rarely done in assembler these days, unless you are working on device drivers or performance-critical applications. In general, high-level languages such as C, C++, C#, Java, and Visual Basic are much more prevalent. There are numerous books dedicated to each of these languages and they cover them in lots of detail. There is still a lot of value in learning assembler, however, as it gives you a better understanding of how the computer really works. One of the best books on computer assembly programming is "The Art of Assembly Language Programming" by Randall Hyde. It covers the Intel x86 assembly language and covers many of the underlying concepts needed for successfully writing programs in assembler.

If you are more interested in programming microcontrollers, there are fewer languages to learn. Many microcontrollers can be programmed using high-level languages such as C or BASIC. This makes programming these devices much easier and also makes the source code much easier to understand after the program has

supply only enough current to maintain the voltage at 6.8 volts. Using an LED as the voltage reference provides some temperature compensation. To adjust the pot, connect a fully charged battery and adjust for 6.8 volts at the battery. If the battery is not fully charged, set the pot at its lowest (toward R4) and check periodically until the voltage rises above 6.8, then back off to 6.8 volts.

The TIP41 will get hot charging a dead battery, so a heatsink is advised. Mouser part number 532-6237B will probably work. TIP41A, B, and C are also okay to use. Mouser has no minimum order (**www.mouser.com**).

Russell Kincaid
Milford, NH

#3 A simple solution would be to use a handful of rectifing diodes, capable of handling the current of the battery charger. Connect the diodes in series to get a 5.5 to 6 volt drop and connect them in series with the six volt battery.

Lance Corey
Fullerton, CA

#4 A battery maintance or float charger just replaces the charge lost due to internal leakage. A resistor can be placed in series with the output of a 12V maintenance charger for use on a 6V battery. If the battery is rated at 24 amp-hours and is dead in 30 days (720 hours), it must be losing charge at a 33 milliamp rate. To drop 6V at 33 mA, use a 180 ohm, 1/2 watt resistor. The resistor value may have to be adjusted to match the actual discharge rate of your battery. If the discharge rate is much higher than 33 mA, look for a sneak discharge path in the tractor electrical system. Another approach is to use an LM117 regulator to drop the maintenace charger output. Set its output to about seven volts.

Joseph D'Airo
West Islip, NY

#5 Here are two sites where six volt chargers are available: **www.atbatt.com/product/6840.asp** and **www.batterystuff.com/battery-chargers/6-volt/UPG6.html**

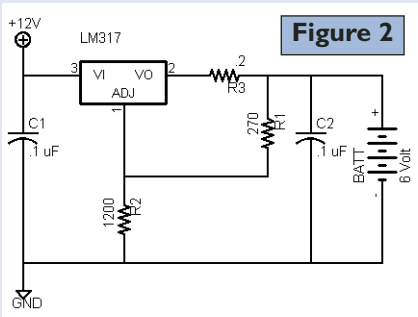

Figure 2

If you want to build your own float charger, refer to Figure 2. A 12 volt DC wall wart such as stock #16770 from **www.mpja.com** can be used with the circuit.

Ed Schick
Harrison, NY

been written. The same books on C and BASIC for computers will apply to microcontrollers with some exceptions. If you want to dive into assembly programming for microcontrollers, there are few places to learn it other than online tutorials and the assembler reference from the manufacturer. Nearly every microcontroller has its own assembly language, each with its own syntax (what you type to tell the device what to do). For PIC microcontrollers, there is an excellent beginner's guide to PIC programming at **www.covingtoninnovations.com/noppp/picassem2004.pdf**. Similar guides for other microcontrollers can be found by searching the Internet.

Rick Altherr
Los Gatos, CA

[#1072 - January 2007]

I'm looking for a phone call screener that would allow me to enter phone numbers of acceptable callers that would ring the phone, but give all other calls a greeting and an option to leave voice mail.

Does anyone know of a commercial product, kit, or design article?

#1 A product that can do exactly that is the "Person-to-Person" from **www.interceptorid.com**. It has a few other features, too. The user manual is available online so you can check it out in more depth.

Colin O'Flynn
Hamilton, Ontario

#2 There are several commercial products: **www.digitone.com/Call%20Screener.htm** and **www.buyreliant.com/tele/f250.htm**

Here is a link to a project that could be easily adapted to your needs: **www.jandspromotions.com/philips2005/Winners/AR1762.htm**

There is a link to download the entire project including source code.

Daryl Rictor
via email

#3 I put together two versions of a PIC and a Caller ID receiver chip to make almost what you are looking for.

My first circuit has your line and answering machine on the input and the 'protected' phones on the output. Over 200 numbers can be programmed in the "allowed" list.

When the line rings, the phones are disconnected and CID data is collected at the end of the ring. Date, time, name, and number data is collected. The name and number data is printed on a 2x16 display and the number is compared to the stored data. If a match is found, the relay connects the phones and the line 'rings' the phones. If there was no match, the relay keeps the phones disconnected and lets your answering machine take the call.

My second version has four relays. The first, "relay 0," handles unknown and unprogrammed calls. The other three are activated by the 11th digit entered while programing the "allowed" numbers. You could connect one machine for the teens, one for your spouse, and one for you. Each could retrieve their own messages without hearing messages directed to others.

More machines could be added by changing the PIC16F876 to a PIC16F877 — 28 pins vs. 40 pins — and adding the needed code in the program.

If you are interested, I can be reached at **dhewett@computingplus.biz**.

Dennis Hewett
via email

#4 You should look at the Globalinx personal communicator manager. If you go to **www.digitone.com/** you will see some options. I bought one and I am demanding more of it than you. For you, it should do the trick nicely. You can program in individual numbers, or partial numbers, to allow or hang up on. You can tell it to store the last number that called in as an accepted number. You can record a greeting on the device that only those not accepted will hear, and then they can be sent to the phone machine (that you must provide). The ones that are accepted are allowed to ring on the house phones without the message.

Depending on how you set it up, you may need a second answering machine for those people (although I use a two-line adapter so both types of calls go to a single machine). If you want Caller ID, you have to put up with the phones ringing two times, to allow the CID data to reach all your phones. This is also programmable. To do more research, try an Internet search on call managers.

Joe Heck
Wrentham, MA

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- Output: 0-30VDC x 2 @ 3 or 5 Amps & 1ea. fixed output @ 5VDC@3A
- Source Effect: $5x10^{-4}$=2mV
- Load Effect: $5x10^{-4}$=2mV
- Ripple Coefficient: <250uV
- Stepped Current: 30mA +/- 1mA
- Input Voltage: 110VAC

CSI3003X3: 0-30VDCx2 @3A **$188.00** 5+: **$183.00**

CSI3005XIII: 0-30VDCx2 @5A **$239.00** 5+: **$229.00**

Details at Web Site > Test Equipment > Power Supplies

Circuit Specialists, Inc. 220 S. Country Club Dr., Mesa, AZ 85210
800-528-1417 / 480-464-2485 / FAX: 480-464-5824

ESD Safe CPU Controlled SMD Hot Air Rework Station

The heater and air control system are built-in and adjusted by the simple touch of the front keypad for precise settings. Temperature range is from 100°C to 480°C / 212°F to 896°F, and the entire unit will enter a temperature drop state after 15 minutes of non-use for safety and to eliminate excessive wear.

- CPU Controlled
- Built-in Vacuum System
- Temperature Range:100°C to 480°C / 212°F to 896°F
- 15-Minute Stand-By temperature "sleep" mode
- Power:110/120 VAC, 320 W maximum

Item# CSI825A++ Sale $149.00!

Details at Web Site > Soldering Equipment & Supplies

Breadboard / Power Supply / MultiFunction DMM Bundle

Provides the user with a quick and efficient system for breadboarding electronic circuits. Comes with three built-in regulated power supplies along with a deluxe, easy-to-use breadboard. Included is a multifunction DMM with 1000VDC, 750VAC, frequency, resistance, diode test, audible continuity, transistor check,temperature, and capacitance.

A Super Deal!

Details at Web Site
> Breadboards & Prototyping Boards

Powered Breadboard w/out DMM: $69.00

Item#: PBB272-DMM: $69.99!

Powered Breadboard w/Multifunction DMM (CSIMS8264)

You Get The DMM for an Extra $.99

Digital Storage Oscilloscope Module

PC based Digital Storage Oscilloscope, 200MHz 5GS/s equiv. sampling USB interface

Convert any PC with USB interface to a high performance Digital Storage Oscilloscope. This is a sophisticated PC basedscope adaptor providing performance compatible to mid/high level stand alone products costing much more! Comes with two probes.

Details & Software Download at Web Site

Price Breakthrough!

> Test Equipment > Oscilloscopes/Outstanding Prices

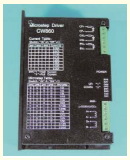
Item# 200DSO Only $819.00

Stepper Motors

Part #:	Motor Frame Size:	Holding Torque:	Price:
42BYGH404	NEMA 17	3.4kg.cm/47oz.in	$17.95
57BYGH207	NEMA 23	8kg.cm/111oz.in	$24.95
57BYGH303	NEMA 23	15kg.cm/208oz.in	$29.95
57BYGH405	NEMA 23	20kg.cm/277oz.in	$34.95
85BYGH350B-03	NEMA 34	48kg.in/665oz.in	$79.95
85BYGH350C-03	NEMA 34	63kg.cm/874oz.in	$119.95

Stepper Motor Controllers 2 Phase Microstepping

Stepper Motor Driver (Bi-polar & Unipolar Motors)



Part #:	Dimensions:	MicroStep:	Price:
XCW220	100mm x 61mm x 19mm	1(200), 1/2(400), 1/4(800), 1/8(1600)	$39.95
CW220	99mm x 65mm x 30mm	1/2(400), 1/8(1600)	$49.95
CW230	115mm x 72mm x 32mm	1(200), 1/2(400), 1/4(800), 1/8(1600), 1/16(3200), 1/32(6400), 1/64(12800)	$59.95
CW250	140mm x 94mm x 45mm	1(200), 1/2(400), 1/8(1600)	$69.95
CW860	147mm x 97mm x 30mm	1(200), 1/2(400), 1/4(800), 1/8(1600), 1/16(3200), 1/32(6400), 1/64(12800), 128(25600), 1/5(1000), 1/10(2000), 1/25(5000), 1/50(10000), 1/125(25000), 1/250(50000)	$119.95

Protek

Protek 2.0 & 2.9GHz Field Strength Analyzers

- Frequency Range : 100KHz ~ 2900MHz (2060MHz for 3201N)
- WFM/NFM/AM/SSB modulated signals may be measured.
- Sweep Trigger Mode: Free Run, Single Run, Continuous Wave, Squelch Run
- Sweep Speed: 500 to 2000msec
- PLL tuning system for precise frequency measurement and tuning
- Built-in Frequency Counter
- RS232 interface

New Rev. Now Available

Item#'s 3290N & 3201N

Details at Web Site

> Test Equipment > RF Test Equipment

Special
$1899.00 (for 3290N)
$1374.00 (for 3201N)

Outdoor Color Speed Dome Camera

- 1/4" **SONY Exview CCD**
- 768(H) x 494(V) effective pixels
- Horizontal Resolution: 480TV lines
- Up to 80 preset points
- Line scanning
- Continuous 360° horizontal rotation
- Vertical rotation: 0-100°
- RS485 control interface
- Min. Illumination: 0.1Lux (color) / 0.001Lux (B&W)

Item# VC-EX861 $899.00

Details at Web Site

Shown with optional wall mount

> Miniature Cameras(Board,Bullet,Mini's, B/W, Color)

SONY Super HAD CCD Color Weatherproof IR Cameras

- Day & Night Auto Switch
- Signal System: NTSC
- Image Sensor:1/3" SONY Super HAD CCD
- Horizontal Resolution: 480TV lines
- Min. Illumination: 0Lux

480 TV Lines Resolution

Item# VC-827D: $132.00

SONY Super HAD CCD™ equipped camera's feature dramatically improved light sensitivity

SONY Super HAD CCD B/W Weatherproof IR Camera

- Day & Night Auto Switch
- Signal System: EIA
- Image Sensor: 1/3" **SONY Super HAD CCD**
- Horizontal Resolution: 420TV lines
- Min. Illumination: 0Lux

Item# VC-317D: $59.50

Details at Web Site

SONY Super HAD CCD Color Camera

- Weather Proof
- Signal System: NTSC
- Image Sensor: 1/4" SONY Super HAD CCD
- Horizontal Resolution: 420TV lines
- Min. Illumination: 1Lux/F1.2

Item# VC-805: $53.95

> Miniature Cameras(Board,Bullet,Mini's, B/W, Color)

SONY Super HAD CCD Color Weatherproof IR Camera

- Day & Night Auto Switch
- Signal System: NTSC
- Image Sensor: 1/4" **SONY Super HAD CCD**
- Horizontal Resolution: 420TV lines
- Min. Illumination: 0Lux

Item# VC-819D: $62.50

Visit our website for a complete listing of our offers. We have over 8,000 electronic items on line @ **www.CircuitSpecialists.com**. PC based data acquisition, industrial computers, loads of test equipment, optics, I.C's, transistors, diodes, resistors, potentiometers, motion control products, capacitors,miniature observation cameras, panel meters, chemicals for electronics, do it yourself printed circuit supplies for PCB fabrication, educational D.I.Y. kits, cooling fans, heat shrink, cable ties & other wire handleing items, hand tools for electronics, breadboards, trainers, programmers & much much more! ***Some Deals you won't believe!***

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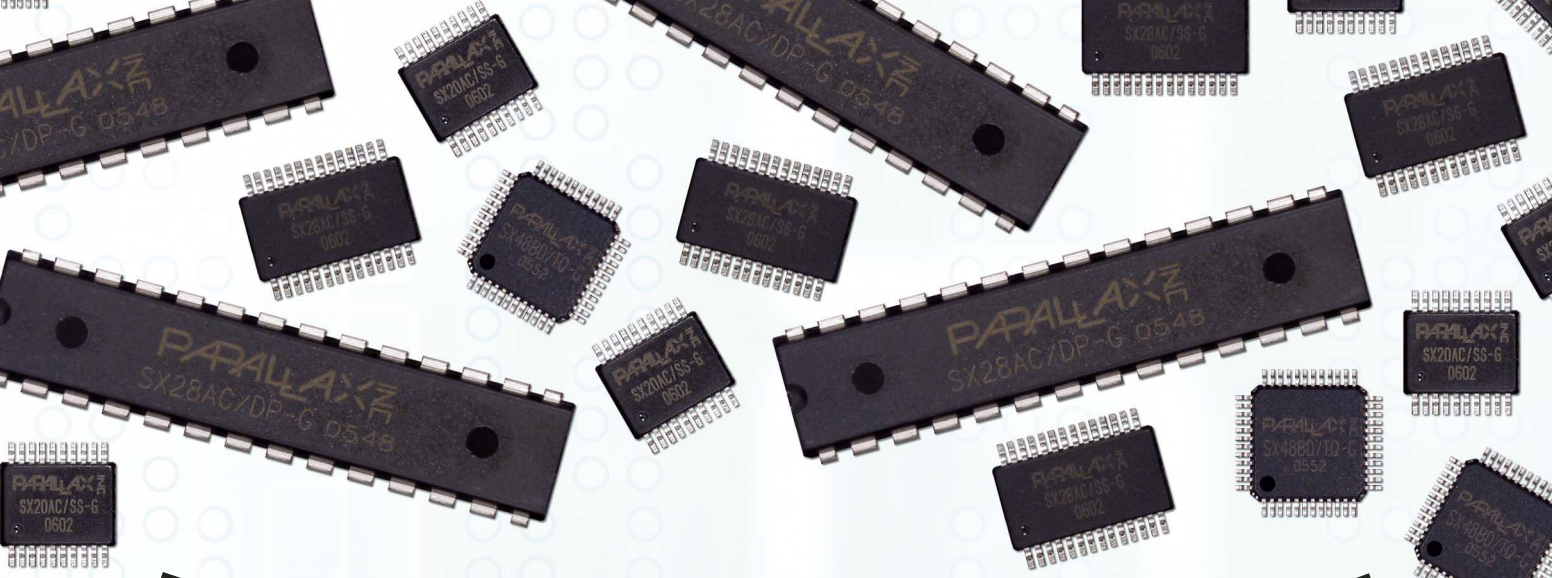

Lower SX Chip Prices!

We have lowered our quantity pricing on SX chips. Now you can continue to use SX microcontrollers in your production projects and enjoy even better pricing. Parallax SX microcontrollers are RoHS Compliant, RISC architecture, high-speed microcontrollers with flash program memory, in-system programming and debugging capability.

Part #	Pins	I/O	EE/Flash	RAM	Qty. 1	Qty. 5	Qty. 100	Qty. 1000
SX20AC/SS-G	20	12	2K bytes	137 bytes	$2.79	$2.51	$2.23	$1.89
SX28AC/DP-G	28	20	2K bytes	136 bytes	$2.79	$2.51	$2.23	$1.89
SX28AC/SS-G	28	20	2K bytes	136 bytes	$2.79	$2.51	$2.23	$1.89
SX48BD-G	48	36	4k x 12 words	262 bytes	$2.79	$2.51	$2.23	$1.89

If you have not yet tried programming with an SX, this is the time to get started. Parallax offers free development software, including SX/B, a BASIC language compiler for the SX microcontroller. The SX/B compiler speeds the programming of SX chips by providing a simple, yet robust high-level language familiar to Parallax customers designed to help the transition from high-level programming (ie. BASIC Stamp®) to low-level programming (assembly language). *For beginners we recommend the SX Tech Tool Kit PLUS (#45181; $99.95) and a 7.5 VDC 1 Amp power supply (#750-00009; $10.95).*

Order Parallax **SX microcontrollers** online at www.parallax.com or call the Parallax Sales Department toll-free 888-512-1024 (Mon-Fri, 7am-5pm, PT).

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